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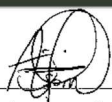

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1. SCOPE

1.1 Application

- 1.1.1 This specification serves as an introduction to the standard engineering specifications.
- 1.1.2 The specifications in this document form the basis of the quality guidelines for this project and serve to set the standards to which individual components as well as the complete installation must adhere. If any deviations from or additions to these specifications should occur, it is detailed in the relevant standard technical specification. In all cases the latest available update of the specifications mentioned, applies to this contract.
- 1.1.3 All material supplied must be new and undamaged and SABS mark-bearing material shall have preference.
- 1.1.4 Works testing and commissioning of equipment is dealt with under the requirements listed in other Engineering Specifications pertaining to the relevant equipment, Engineering Standards and Particular (or Project or Detail) Specifications.

1.2 General

- 1.2.1 The following definitions are used in these Specifications:
 - a) The term “Employer” shall mean the person named as employer in the Appendix to Tender and the legal successors in title to this person;
 - b) The term “Contractor” shall mean the person(s) named as contractor in the letter of Tender accepted by the employer.
 - c) The term “Engineer” shall mean the person appointed by the Employer to as the Engineer for the purposes of the contract.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification identifies the Employer's standard modifications and requirements which shall be applied to the statutory and recognised standards. The detailed specification of the project or site specific requirements will be found in the Project Specification and its accompanying Technical Data Sheets, which shall be read in conjunction with this Specification and any other applicable Standard Specification documents.
- 2.1.2 The decreasing order of precedence of these requirements shall be as follows:
- a) Statutory requirements
 - b) Employer's requirements
 - c) Project Technical Specifications:
 - i) Drawings
 - ii) Technical Data Sheets
 - iii) Aurecon Standard Engineering Specifications
 - d) National and international standards
- 2.1.3 Any items not specifically detailed in this Specification, which are necessary to provide a safe and fully operational working system, shall be deemed to be included.
- 2.1.4 The Contractor shall operate an auditable quality assurance procedure covering the design, construction, inspection and testing of the Installation.

2.2 Regulations, Specifications and Standards

- 2.2.1 The complete installation shall comply with all the latest editions (current at the time of Tender) of all relevant documents listed in the tables below, including:
- a) Construction Regulations 2003 issued in terms of Section 43 of the Act;
 - b) Local Fire Regulations; and
 - c) Regulations of the Local Supply Authority.

Table 1: National Statutory Regulations

ACT No. / Year issued	Description
41	Electricity Act
85/1993	Occupational Health and Safety Act
29/1996	Mines Health and Safety Act
50/1991	Minerals Act
73/1989	Environmental and Conservation Act
31/1963	Fencing Act
122/1984	Forest Act
63/1970	Mountain Catchment Areas Act

Table 2: Guidelines and Recommended Standard Codes of Practices

No. / Year Issued	Description
SAIC/1990	SA Steel Construction Handbook
NWP 3109	Standard Drawing Practice
TMH1/1986	Standard Methods of testing Road Construction Materials
CSRA / 1987	Standard Specification for Road and Bridge Works
SANS 0157	Quality Management System
SANS 03	Code of Practice – Protection of structures against lightning
SANS 0292	Code of practice for the application of CNE on low voltage distribution systems
NRS 023/1991 (DTS 0090)	Overhead Reticulation: Recommended practice for low cost urban reticulation
SANS 10142-1	Standard Code of Practice for the Wiring of Premises - Low Voltage
DTS 0060	Power line crossings of proclaimed roads, railway lines, tramways and important communication lines
SANS 10280	Code of Practice for Overhead Power Lines for Conditions Prevailing in South Africa

Table 3: SANS/NRS/BS/ANSI/IEC and Other Specifications

SANS/SANS	Other Spec	Description
<u>ELECTRICAL</u>		
SANS 1418, Part 1 tot 3 DTS 0105 (NRS 018)		Aerial Bundled Conductor
	NRS 051	ABC – Suspension and Strain fittings
SANS 135		Bolts and Nuts
SANS 178		Bolts, Eye
SANS 1195		Busbars
SANS 1632	BS 6290	Batteries
SANS 1652		Battery Charger
	BSS 3858	Binding/Identification Sleeves for Cables and Wires
SANS 1268 : 1979 NRS 016 : 1991		CNE
SANS 0198 : 1988		Cables, installation of electric
NRS 012 : 1991 SANS 1507		Cables, low voltage - Solid Dielectric Insulation (PVC) 300/500 to 1900/3300V
SANS 150 - 1970		Cables – PVC Insulated and Flexible Cords
NRS 013 : 1991		Cables, medium voltage
		Cables – Cross-Linked Polyethelene (XLPE) 3.8/6.6 to 19/33kV
SANS 97/91		Cables – PILC 3.3/3.3 to 19/33kV
SANS 1507-6		Cable (house service split concentric) – Airdac
SANS 1507-6		Cable (House service concentric) - Airdac
SANS 1213 SANS/IEC 60529		Cable Glands
	NRS 028	Cable lugs and ferrules
	NRS 075	Cable lugs and ferrules – Mechanical Torque sheer connectors

SANS/SANS	Other Spec	Description
SANS 808		Cable Ties
DTS 0086 (NRS 020)		Clamps (strain for split concentric)
DTS 0086 (NRS 020)		Clamps (suspension for split concentric)
SANS 178		Clamps Strain
SANS 178		Clevis Tongue Adaptor (twisted)
SANS 10142		Clips for Wiring
SANS 1091		Colours - Standard
	BS 3288 Part 1 (Tests)	Compression Fittings
SANS 470	DTS 0106	Concrete Poles
SANS 182		Conductor ACSR/AAC and AAAC
DTS 0087 (NRS 021)		Conductor, Covered
		Conduit Saddles
		Conduit
NRS 028		Connectors, lug/termination
EDF 6737/HN 33 E60 (Main cable 350 mm ² to 70 mm ² take off 6 mm ² to 35 mm ²)		Connectors, insulation piercing
	BS 3288 (Tests)	Connectors, mid-span/full tension
SANS 0162		Connectors, mid-span/no tension
SANS 1200 H/HA		Connectors
SANS 1092		Contactors
SANS 0162		Cross Arm Braces
SANS 1200 H/HA		Cross Arms
SANS 1063		D Fuses
	IEC 60529	Degrees of Protection of Enclosures for LV SG en Control
SANS 0199 SANS 1063 SANS 1524-1		Earthing rods, couplers & clamps
	NRS 009-1	Electricity Dispenser
	BSS 152	Electric Power Switchgear and Associated Apparatus
SANS 1222		Enclosures for electrical equipment classified by IP code
	NRS 008	Enclosures to Cable terminations in Air: For rated AC voltages of up to 7.2kV and up to 36kV
	BSS 1767	Grommets
SANS 8528		Generators – Diesel Alternators Sets
SANS 0198/1988		Installation of electric cables
SANS 177		Insulators for Overhead Lines above 1000V
SANS 950		Impulse Tests for Power Cables
	NRS 068	Indicator – Earth Fault
	NRS072	Indicator – Overhead line fault path indicator
	BSS 158	Marking and Arrangement for Switchgear Busbars Main and Auxiliary Wiring
SANS 156		Moulded Case Circuit Breakers
SANS 1029		Miniature Substations
SANS 1091		National Colour Standards for Paint

SANS/SANS	Other Spec	Description
SANS 0200		Neutral earthing in medium voltage industrial power systems
SANS 555		Oil – Mineral for Transformers, Switchgear
	BSCP 1014	Protection of Electrical Power Equipment against Climatic Conditions
SANS 1619		Ready Boards
	NRS 036	Re-closers – Pole Mounted
	DTS 0104 (NRS 032)	Service box
		Stainless Steel Straps and Buckles
SANS 0162	BS 16	Stay Assemblies
SANS 0162	BS 16	Stay Attachment Brackets
SANS 0162	BS 16	Stay Insulators
SANS 182, Part 5		Stay Wires
SANS 1507		Suffix Wiring
SANS IEC 99-4	NWS 1108 BS 2914	Surge Diverters
SANS 171		Surge Arresters – Low Voltage
	NRS 039	Surge Arresters – Medium Voltage
SANS 1186 / 1978		Symbolic Safety Signs
	NRS 036	Switchgear: Metal Clad – 1 to 24kV AC RMS
SANS1874	NRS 006 BS 5227	Switchgear: Metal Enclosed Ring Main Units – 1kV AC to 24kV AC RMS
SANS 60439		Switchgear and Control Gear Assemblies – Low Voltage – Requirements for Type testing
SANS 60947		Switchgear and Control – Low Voltage Part 1 General Rules Part 2 Circuit Breakers Part 3 Switches/Isolators/Switch Isolators and Combination switches
SANS IEC 947-4-1		Switchgear & Control Gear – Low Voltage
	NRS 035-1	Switchgear – Drop-out Fuse link, Solid Links, Pole mounted – up to 33kV
	NRS 036	Switchgear: Sectionalisers and Reclosers – Pole Mounted
	NRS 046	Switchgear: Load-break Disconnectors, Pole mounted, to 36KV
	BS 464	Thimbles
SANS 780		Transformers, Self-protected
	NRS 054, BS 171 IEC 60076; NWS 1532	Transformer - Power
SANS 780		Transformer - Distribution (2 MVA Max)
	NRS 02 IEC 44 IEC 185	Transformers – Current: 3,6kV to 420kV

SANS/SANS	Other Spec	Description
	NRS 030 IEC 44 IEC 185	Transformers - Voltage
	NWS 1827	Transmission line hardware
SANS 60-2		Test Techniques for High Voltage – Measuring Systems
SANS 135		Washers
SANS 182		Wire, PVC Covered
BS 462		Wire Rope Grips
		Wire, Stranded Copper, bare
SANS 753		Wood Poles – Pine
SANS 754		Wood Poles – Gum
		Zinc coatings, hot dipped galvanized
	IEC 60871-1	Shunt Capacitors
	IEC664	Insulation Coordination - LV Networks
	IEC 71	Insulation Coordination – above 1kV
	IEC 273	Dimensions of Post Insulators
	IEC 168	Tests on Insulators
	IEC 815	Guide for selection of insulators for polluted conditions
	IEC 62271-200 (Prev 60298 & 60694)	Construction of medium voltage switchgear and control gear assemblies
	IEC 62271-100	Construction of medium voltage circuit breakers
	IEC 62271-102	High voltage alternating current disconnectors and earthing switches
	IEC 60076-6	Iron Core Reactors
	IEC 60549	High Voltage fuses for external protection of power capacitors
	IEC 60420	High Voltage Contactors
SANS / IEC 694		Common Clauses for HV switchgear & control gear standards
	IEC 44-4	Tests – Partial Discharge - Measurement
	IEC 270	Test – HV Testing methods, measurements of partial discharge
	IEC 60-1,2 & 3	Tests – HV – Test Techniques
	IEC 70	Capacitors
<u>CIVILS AND OTHER</u>		
863		Comprehensive Strength of Concrete
862		Slump of Fresh Mixed Concrete
044/1963		Welding and Welding Symbols
0162/1993		The structural use of steel
0100/1992		The structural use of concrete
0400/1987		Standard specification for the application of National Building Regulations
0144/1987		Detail of steel reinforcement for concrete
1200		The standard specification for civil engineering and construction

SANS/SANS	Other Spec	Description
1024/1974		Welded mesh for concrete reinforcing
1186/1978		Symbolic safety sign
920/1985		Steel bars for concrete reinforcement
986/1970		Pre-cast reinforced concrete culverts
831/1971		Portland Cement 15
471/1971		Portland Cement
626/1971		Portland blast furnace cement
677/1986		Non-pressure concrete pipes
675/1993		Zinc coated fence wiring
SANS ISO 1461/1999		Hot dip (galvanised) zinc coatings
10240/1997		Hot dip (galvanised) zinc coatings
558/1973		Cast iron surface boxes and manhole and inspection covers & frames
82/1976		Bending dimensions for bars for reinforced concrete
1083/1976		Aggregates from natural sources



3. PERFORMANCE WARRANTY

- 3.1.1 The Contractor/Supplier shall guarantee the performance of the equipment to meet the duties and the technical requirements included in this specification and associated specification and requirements of which this specification forms part of. A minimum guarantee period of 12 months is required.
- 3.1.2 Failure to meet the performance and other requirements herein (and associated specifications and requirements it forms part of) shall deemed to be a defect and the Defects Liability Clause in the General Conditions of Contract will apply.

4. SIGNAGE, NOTICES AND LABELLING

4.1 Danger Notices and Phase Identification Disks

- 4.1.1 Approved danger notices shall be mounted at all structures fitted with transformers, remote mechanically operated switchgear, distribution boards, capacitors, reactors, open cables or other live apparatus, and at other positions as may be decided by the Engineer. They should be written in the appropriate official languages of the Region. The internationally approved electrical warning sign (black lightning beam on a yellow background) shall also be clearly visible on the notice. Notices shall be mounted on the wooden poles, at a height of three meters above ground level and on steel structures and fences at a clearly visible height. Writing must be easily discernible letters.
- 4.1.2 All transformers, drop-out fuses, gang-operated links, terminal and T-off structures and busbars must be equipped with phase identification disks on the high voltage side. These must be red, white and blue, corresponding to the phases and be fixed around the connecting studs of the transformer bushings or around the conductor where it terminates on the units in question.

4.2 Marking and Labelling

- 4.2.1 All equipment shall be labelled according to the table below. Trefolite shall be used for all indoor labels and Aluminium shall be used for all outdoor applications.

Table 4: Marking and Labelling

Item	Device	Language of Inscription	Colours	Plate Dimensions (mm)	Letter Height (mm)	Stroke width (mm)
1	Outdoor Labels					
1.1	Circuit/Busbar	English	Black on orange	200 high	150	15
1.2	Phase identification		Red/Yellow/Blue	100 dia	-	-
1.3	Yard gear, items	English	White on black	As required	70	10
1.4	Kiosks, junction boxes	English	Black on white	As required	15	2
2	Indoor Labels					
2.1	GIS	English	Black on orange	As required	As required	As required
2.2	Equipment labels	English	Black on orange	As required	15	2
2.3	Panel labels	English	Black on white	As required	25	3
2.4	Panel equipment labels	English	Black on white	As required	5	1
3	Danger, Caution	English and Afrikaans	Red on white	As required	25	3

4.3 Labelling of Cables

Labelling of cables should be in English and be unambiguous, durable and legible. Labels should be attached directly to the cable to which they refer. Labels must be attached to cables using appropriate corrosion resistant, mechanical fixings.

The cable should be labelled on both ends indicating where it is running from and where it is going to. The fixing of the cables shall not affect the IP rating of the cable.

4.4 Paint Colours

Colours to be used for equipment shall be in accordance SANS 1091. Standard available colours and the typical equipment, to which they will be applied, are listed in the table below. All paintwork shall have a "Texture" finish and not a "Mat" or "Glossy" finish, unless specified otherwise elsewhere in the documentation.

Table 5: Paint Colours

Colour No.	Colour Name	Application
A11	Signal Red	Incomer panels and Emergency feeder panels
C12	Avocado Green	Outdoor Kiosks, Miniature Substations and Transformers
F11	Strong Blue	Bus-section Coupler
G12	Dark Admiralty Grey	3.3, 11 and 22 kV Switchgear
G29	Light Grey	3.3 kV Switchgear for Power Factor Correction
G35	Navy Light Grey	Steel Structures
C37	Light Stone	Miniature Substations, Transformers, MV Switchgear, Kiosks etc.
F06	Dark Violet	UPS Supply
B26	Light Orange	LV DB's and MCC's

5. CLEARANCES OF OUTDOOR BUSBARS, CONNECTIONS AND OVERHEAD LINES

5.1 Minimum Clearances of Outdoor Busbars and Connections

Minimum clearances of outdoor busbars and connections are summarised in the table below. In the case of the minimum clearance not complying with the requirements in the table below, insulation for the full operating voltage will be done with heat shrinkable insulation material suitable for outdoor application.

Table 6: Clearance distances in the table below are expressed in meters

	Rated System Voltage kV										
	≤ 12	24	36	72	100	123	145	245	300	362	420
Minimum clearance between live metal and earth	0.20	0.30	0.38	0.70	1.00	1.15	1.30	2.00	2.40	2.80	3.36
Minimum clearance between live metal of different phases	0.25	0.34	0.43	0.82	1.16	1.22	1.50	2.30	2.80	3.40	3.90
Minimum safety clearance between live metal and positions to which access is permissible with other equipment alive	2.60	2.80	2.90	3.00	3.50	3.60	3.80	4.50	4.80	5.30	5.50
Minimum clearance from ground level to base of insulation	2.5										

5.2 Earth Conductor Sizes

Table 7: Minimum sizes of Copper earth conductors (in mm²) are summarized in the table below

RATED SHORT CIRCUIT CURRENT (kA)		8,0	10,0	12,5	16,0	20	25	31,5	40,0
Minimum cross section area for a conductor required to carry full fault current									
3 s rating	mm ²	61	76	95	122	153	191	241	306
1 s rating	mm ²	35	44	55	71	88	110	139	176
Minimum cross sectional area for a conductor in a mesh system									
3 s rating	mm ²	40	51	63	81	102	127	160	204
1 s rating	mm ²	23	29	36	47	58	73	92	117

5.3 Overhead Line Clearances

Safety clearances of overhead lines are listed in the table below and will at all times be adhered to.

Table 8: Clearance (at maximum sag or swing as applicable)

1	2	3	4	5	6	7	8	9	10	11
	Ground		Above	Above Township Roads (m)	Along Roads Parallel with entry/exit (m)	Across Communal land (m)	Across Private property (m)	Telkom Insulated (m)	Buildings & structures (m)	Other Power lines (m)
	Outside Towns (m)	Inside Towns (m)	Railways and Main Roads (m)							
MV										
24 kV	5,2	5,5	6,4	5,5	5,5	5,5	5,5	0,9	3,0	0,9
12 kV	5,1	5,5	6,3	5,5	5,5	5,5	5,5	0,9	3,0	0,8
7,2 kV	5,0	5,5	6,2	5,5	5,5	5,5	5,5	0,9	3,0	0,7
LV bare wire										
420 V/230 V	4,9	5,5	6,1	5,5	5,5	5,5	5,5	0,6	3,0	0,6
LV insulated										
ABC 420 V/230 V	-	3,3	5,1	4,7	3,5	3,3	3,3	0,2	3,0	0,6
Concentric 230 V	-		5,1	4,7	3,0	3,0	2,5	0,2	3,0	0,6

An LV or Telkom pole position at MV midspan is considered to be a separate structure, hence 3 m clearance required.

NOTES

- Column 2 is the minimum clearance of conductor to ground outside built-up areas.
- Column 3 is the minimum clearance of conductor to ground inside built-up areas.
- Column 4 is the minimum clearance to railway lines and proclaimed roads.
- Column 5 is the minimum clearance to unproclaim roads used by vehicles such as delivery vans and buses.
- Column 6 is the minimum clearance to ground where lines run parallel to any road used by vehicles and vehicle entries/exits to the road cross underneath the line.
- Column 7 is the minimum clearance to ground in areas used by the community such as tracks or walkways.
- Column 8 is the minimum clearance to ground in an area owned by one owner.
- Column 9 is the minimum clearance to Telkom cable supported on the same structures.
- Column 10 is the minimum clearance to buildings and structures not forming part of the network, including a LV/Telkom pole installed midspan underneath a MV line.
- Column 11 is the minimum clearance to other power lines excluding the conditions listed in column 9.

6. STANDARD INSULATION LEVELS FOR WINDINGS AND CONNECTED PARTS

All Transformers shall comply with the standard insulation levels as is summarised in Table 9 below.

Table 9: Standard insulation levels for windings and connected parts (SANS 780:2009)

1	2	3		4	5
Highest r.m.s voltage U_m for equipment kV	Nominal System r.m.s Voltage U_m	Insulation level			
		Lightning impulse test voltage, peak kV		Power-frequency test r.m.s voltage kV	
		List 2 ^a	List 3 ^b	Separate source voltage withstand	Induced voltage withstand
≤1,0		25	30	2,5	Twice the rated voltage at principal tapping
3,6	3,3	40	60	16	
7,2	6,6	60	75	22	
12	11	75	95	28	
24	22	125	150	50	
36	33	170	200	70	
^a List 2 values apply to transformers designed for non-exposed installations (such as those connected to cable networks)					
^b List 3 values to apply to transformers designed for exposed installations					

Transformers shall comply with the standard insulation levels and Creepage distances as summarised in Table 10 below.

Table 10: Transformer Minimum Insulation, Fault and Creepage distances for power transformers (Extract from Eskom NWS Specification)

System highest voltage U_m (kV _{rms})	System nominal voltage U_n (kV _{rms})	System fault level (kA)	Lightning impulse voltage withstand level at sea level (BIL) (kV peak)		60 s power frequency voltage withstand level at sea level (60s 50Hz)		Bushings				Creepage (31mm/kV)	Tap changer		
							Line		Neutral					
			Line Terminal	Neutral Terminal	Separate source	Induced	BIL (kV peak)	60s 50Hz (kV _{rms})	BIL (kV peak)	60s 50Hz (kV _{rms})		System nominal voltage (U_n) (kV _{rms})	BIL (kV peak)	60s 50Hz (kV _{rms})
3.6	3.3	20	45	45	16	6,6	200	70	200	70	110	3.3	45	16
7.2	6.6	25	75	75	22	13,2	200	70	200	70	220	6.6	75	22
12.0	11	25	95	95	28	22	200	70	200	70	375	11	95	28
17.5	16	20	110	110	38	32	200	70	200	70	540	16	110	38
24	22	20	150	150	50	44	200	70	200	70	740	22	150	50
36	33	20	200	200	70	66	250	95	250	95	1100	33	200	70
48	44	20	250	200x	70x	95	350	140	250	95	1500	33	200	70
72	66	20	350	250x	95x	140	380	150	350	140	2250	44	250	95
100	88	25	380	250x	95x	150	550	230	350	140	3100	44	250	95
145	132	40	550	250x	95x	230	650	275	350	140	4500	44	250	95
145	132	40	550	110+	38+	230	650	275	350	140	4500	16	110	38
Non uniform insulation		+ Fully graded insulation												
		x Partially graded insulation (see 4.9.6 Insulation tests, fault and creepage levels)												

NOTE 1: Phase-to-phase values specified in this table for all transformer windings shall be designed to withstand the appropriate test voltages, and shall be tested as specified in 5.2 Test by the Manufacturer.

NOTE 2: 145kV values specified in the last table are for Auto Transformers only.



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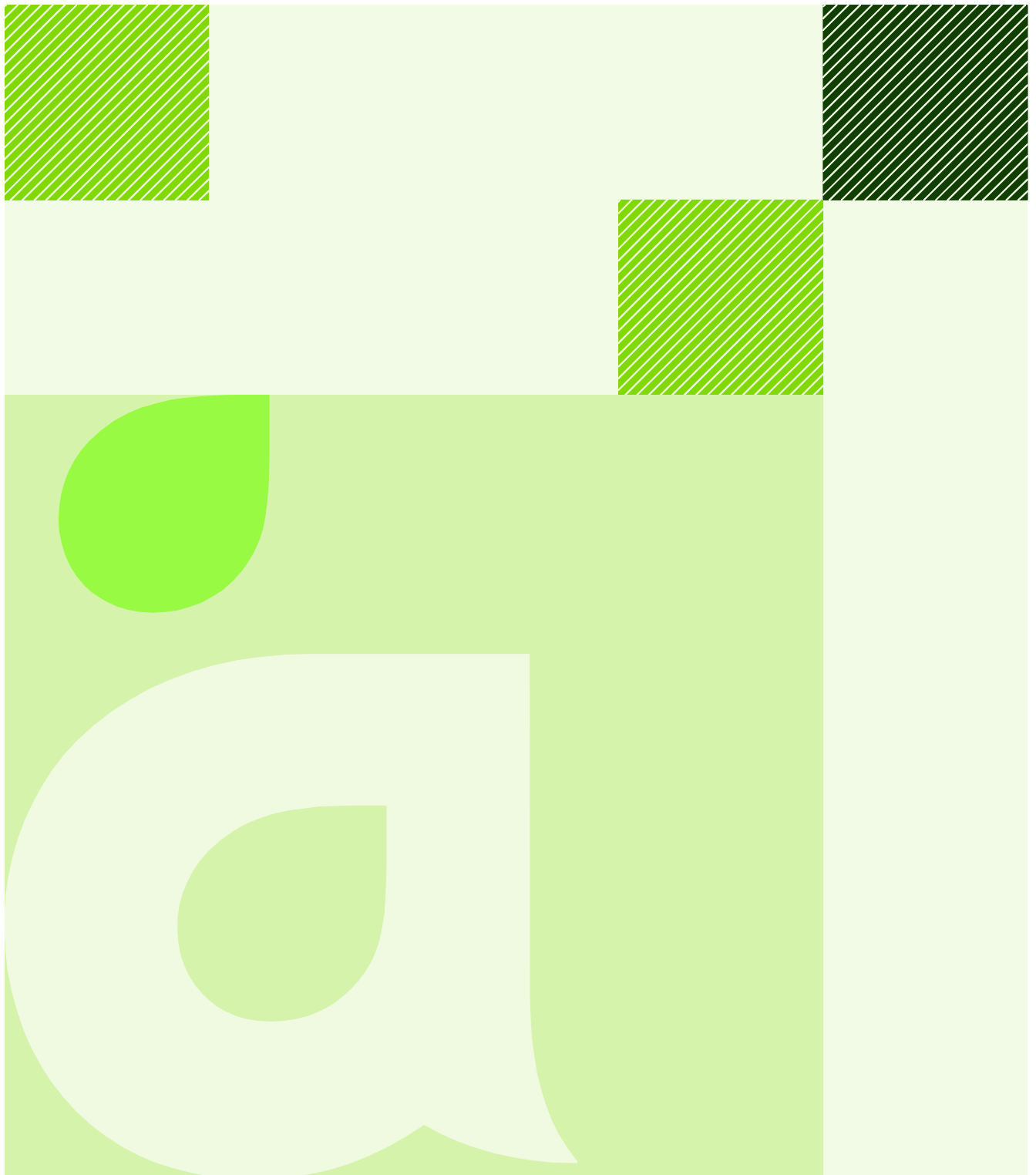
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Engineering Specification

Training, Testing and Commissioning

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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification covers the general requirements for the factory and on site testing and commissioning requirements for all equipment supplied and installed under this contract. The procedures described are the minimum required and additional tests/requirements are specified in the relevant standard and detail specifications.
- 1.1.2 This Specification identifies the standard procedures and requirements for factory inspection tests, site testing, commissioning and training. The detailed requirements for each portion of equipment shall be found in the testing and commissioning subsection of the relevant equipment's standard specification. Further detailed requirements of the project or site specific requirements shall be found in the Particular Specification and its accompanying Data Sheets, which shall be read in conjunction with this Specification.



2. FACTORY INSPECTIONS

2.1 General

- 2.1.1 The Contractor shall provide Works, factory and manufacturers test information, including certificates of conformity to the Engineer. They shall be complete, accurate, in accordance with the specifications and approved by the Engineer prior to the equipment leaving the factory.
- 2.1.2 These tests include all the inspections required by the Engineer, or Manufacturer (with associated testing results/reports to prove it) during the Factory Construction process.
- 2.1.3 The Contractor (and relevant manufacturers) shall operate an auditable quality assurance procedure covering the design, construction, inspection and testing of the industrial information and communications network.
- 2.1.4 The design, construction, inspection, testing and commissioning of the equipment shall comply with all relevant Statutory Regulations, and the latest editions (current at the time of Tender) of all relevant South African National Standards.

3. SITE TESTING AND COMMISSIONING

3.1 General

- 3.1.1 The full system testing of the electrical, instrumentation and control works are critical to the success of the project, therefore the Contractor shall execute it with the necessary diligence.
- 3.1.2 All new, refurbished or modified plant and equipment shall be thoroughly tested and commissioned prior to the handing over. Only plant and equipment that can be demonstrated to conform to the project specifications, relevant codes of practice and legislation, SANS, British, and IEC standards shall be handed over to the Employer.
- 3.1.3 During testing and commissioning the Contractor shall be responsible for providing all labour and materials (including testing equipment) and shall carry out all the servicing and any adjustment of the plant required for ensuring that it operates as specified.
- 3.1.4 Valid calibration certificates shall be available for all testing equipment on site during the commissioning and testing period.
- 3.1.5 Testing and commissioning activities shall be carefully planned, documented, and managed by the Contractor.
- 3.1.6 For details on the tests and inspections required for equipment refer to the relevant sub sections of the different equipment standard specifications.
- 3.1.7 All costs for equipment, labour and other expenses for the on-site testing and commissioning of equipment shall be included in the tendered rates for testing and commissioning as set out in the measurement and payment clauses of each piece of equipment and in the schedule of quantities. Any additional tests specified in the standard and detail specifications shall also be included in the tendered rates.
- 3.1.8 The Contractor shall:
 - a) Demonstrate the functionality of the plant and all operator interfaces. This shall include demonstration that the control system can perform as intended by the designer, over the full range of foreseeable operating conditions.
 - b) Carry out full site tests on completion of installation work, irrespective of the extent of any previous partial or sectional tests or works tests that is specified in other standard specifications.
 - c) Provide method statements for tests and commissioning activities, together with the range of values and settings that are in accordance with the detailed design and demonstrate compliance with the specifications, for inclusion in the Commissioning Plan.

3.2 Testing Sequence


- 3.2.1 The testing to be performed on site is divided into two sections as follows:
 - a) Before official commissioning commences the Contractor shall test his equipment as described below to ensure that the plant has been installed correctly.
 - b) After the Contractor has been satisfied that the equipment is in working order, the commissioning of the plant will commence in the presence of the Engineer as described below.

3.3 Site Testing of Equipment Prior to Commissioning

- 3.3.1 The Contractor shall timeously inform the Engineer when he intends to perform his first tests and start-up of equipment in order to allow a representative of the Engineer to witness the tests if the Engineer deems it necessary.
- 3.3.2 Before starting up any section of the plant or equipment, the Contractor shall clean out the housings and equipment or structures, and, if necessary, make arrangements with other Contractors to remove their building rubble from the structures, check that all safety devices and alarms have been set and activated, all nuts and cable terminations have been tightened correctly, that all the equipment is complete and ready for start-up, that the plant has been installed correctly, and that three copies of the operating manuals have been handed over to the engineer.
- 3.3.3 Each section of the equipment shall be started up by the contractor. Before any equipment is started or energized, the contractor shall ensure that it is safe for personnel and equipment on site to do so. Allowance for these costs shall be made in his tendered rates and sums.
- 3.3.4 The Contractor shall conduct his own tests on the equipment and, only when he is satisfied that these tests meet the requirements of the specifications, shall he notify the engineer that he is ready to conduct the official tests on completion. The Contractor shall not conduct an official test without the Engineer being present or his approval to do so. All equipment tested shall conform to the requirements specified.
- 3.3.5 The Contractor shall:
- a) Perform and record the results of all testing.
 - b) At each stage carry out such preparatory testing and commissioning as necessary to ensure that equipment is ready for witnessing by the Engineer.
 - c) Retain all documentation generated during the testing and commissioning process, including all test and performance data, as a commissioning record and issue four copies as part of the contract documentation.
 - d) At each stage of testing the results shall be checked by the Engineer.
 - e) Commissioning shall only proceed to the next stage if the results are approved by the Engineer. Any corrective measures shall be agreed by the Engineer.


3.4 Prerequisites for Commissioning

- 3.4.1 The Contractor shall provide Works testing, factory acceptance testing and manufacturers routine testing information and certificates of conformity to the Engineer. The documentation shall be complete, accurate, in accordance with the specifications and approved by the Engineer prior to the start of the commissioning.
- 3.4.2 All instruments and equipment used for testing and commissioning shall be controlled by a quality assurance scheme acceptable to the Engineer, and their accuracy and suitability shall be demonstrated by the Contractor.
- 3.4.3 Operation and Maintenance Manuals for the whole works shall be provided before commissioning commences.
- 3.4.4 The comprehensive training programme, which shall include the training manual, shall be provided for the training that will take place during the commissioning period.
- 3.4.5 All labelling of equipment and cabling shall be completed and correct.
- 3.4.6 The Contractor shall ensure all warning notices, guards and safety devices are installed.

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- 3.4.7 All pre-commissioning tests and checks shall be agreed with the Engineer prior to the commencement therewith.
 - 3.4.8 When all the tests required before commissioning, or tests before tests on completion, have been completed and accepted by the Engineer, the commissioning may proceed.
 - 3.4.9 Testing and Commissioning activities shall be carefully planned, documented, and managed.
 - 3.4.10 The Contractor shall provide the Engineer with full details of his testing and commissioning activities and programme for approval.

3.5 Final Commissioning

- 3.5.1 The Contractor shall be responsible for commissioning all sections of the works and shall perform all of the tasks set out below:
 - a) Prior notice of and proper arrangements for the commissioning shall be made with the Employer, Engineer, supply authority, and all Contractors and suppliers of equipment, which will be affected by the commissioning operation.
 - b) If plant and equipment, which has been supplied by others has to be commissioned, the relevant contractor's permission thereto, together with any specific requirements relating to commissioning shall be obtained prior to commissioning.
 - c) All sections of the works shall be carefully inspected by a responsible representative of the Contractor to ensure that all construction and installation work has been properly completed.
- 3.5.2 Commissioning and testing on site shall be carried out by experienced personnel under the Contractor's supervision.
- 3.5.3 The commissioning period shall be undertaken over a trouble-free period of at least thirty consecutive calendar days. During this period the Contractor shall instruct the operating staff in the correct procedures of operating the plant under all circumstances of operation, including emergency conditions, the correct servicing of every part, the type of oil or grease to be used, and similar instructions. This shall be done by demonstration and confirmation, in writing, and operating manuals shall be referred to for this purpose.
- 3.5.4 At least three weeks before commissioning commences the Engineer will be requested to provide the Contractor with commissioning sheets for all the equipment installed by the Contractor. These forms shall be completed by the Contractor during the commissioning period and all items listed shall be entered. Final hand-over certificates will not be issued for equipment with incomplete commissioning reports. Information that is not available or applicable, or reasons for not performing certain tests shall be agreed with the Engineer.
- 3.5.5 The thirty day commissioning period will commence with a day-one test and terminate with a day-thirty test in compliance with the commissioning report. Commissioning of the plant (which includes the thirty days between the day-one and day-thirty tests) shall include operating under conditions which shall adequately prove that all the specifications are met. All safety devices, stand-by plant, automatic controls and protection devices shall be adequately tested for reliability and correct functioning. The Contractor may be called upon to repeat testing during the maintenance period if the performance of any equipment supplied under this contract is suspected to be substandard by the Engineer. Such tests shall be for the Contractor's account and shall comply with the requirements specified. Copies of updated commissioning reports shall be provided to the Engineer within two days after a test has been performed.
- 3.5.6 Programs for the day-one tests, day-thirty tests and instruction/training sessions with the client shall be prepared by the Contractor and provided to the Engineer no less than two



weeks before the commissioning period commences. Weekly updates to these schedules shall be provided by the Contractor for the duration of the commissioning period.

- 3.5.7 Note that if any equipment should fail during the 30 day commissioning period, the equipment shall be repaired or replaced by the Contractor, and testing and commissioning will commence from scratch.
- 3.5.8 During the thirty-day commissioning period, the Contractor shall be responsible for providing all labour and materials (including testing equipment) and shall carry out all the servicing and any adjustment of the plant required for ensuring that it operates as specified. Valid calibration certificates shall be available for all testing equipment on site during the commissioning period.
- 3.5.9 The Contractor shall conduct all the tests required to satisfy the Engineer that the plant is capable of performing in accordance with the specification, and shall make allowance therefor in his tendered rates and prices. Any defects detected during the commissioning period shall be made good by and at the expense of the Contractor, including all additional costs incurred by the Employer and his representatives and the Engineer. These tests shall be conducted to certify that the plant, as installed, is operating in accordance with the specified requirements. Note that all equipment will be tested as part of a system where appropriate, and will not be passed if all protection devices, interlocking with other equipment, etc. is not fully functional.

3.6 Commissioning Report

- 3.6.1 A comprehensive commissioning test report shall be submitted by the Contractor prior to the issue of the Certificate of Completion and shall be inserted in the operations and maintenance manual.
- 3.6.2 After the Contractor has provided training to the Employer and provided all other contractual requirements have been met, the latter will sign the commissioning report.
- 3.6.3 Once a commissioning report is complete, the Engineer and the Contractor will sign and date the report, whereupon the Engineer will notify the Employer that maintenance for that particular piece of equipment from then on is the Employers responsibility in compliance with the general conditions of contract.

4. TRAINING

4.1 General

- 4.1.1 The Contractor shall conduct comprehensive training courses for designated personnel in the maintenance and operation of the plant during the commissioning period.
- 4.1.2 Electronic equipment operation and maintenance training shall form part of the overall training programme.
- 4.1.3 All equipment shall be in a complete working order before training shall commence.
- 4.1.4 The training shall be designed specifically for the works and shall take into account the skill and experience levels with the installed works of personnel.
- 4.1.5 Unless otherwise specified the training shall allow for at least 4 operational staff members and 4 engineering staff members.
- 4.1.6 Where the Contractor engages specialist services for sophisticated equipment, sufficient time shall be allowed in the contract to permit expert training to be given to plant operatives and maintenance personnel.
- 4.1.7 Where the Contractor presents portions of the course material by audio visual means, copies of those audio visual presentations shall be delivered to the Employer as part of the printed training manuals.
- 4.1.8 The Employer reserves the right to videotape the training sessions for later use.
- 4.1.9 During the installation phase, the Employer may wish to nominate a person who will be closely involved with the installation and commissioning process. The intention is not to interfere with the Contractors' installation team, but to do observation in order to obtain the maximum possible information regarding the installation, to enable efficient maintenance to be undertaken by the Employer after final hand-over and expiring of the guarantee period.

4.2 Training Manual

- 4.2.1 Training and training manuals shall be based on the O&M Manuals.
- 4.2.2 Training manuals shall be delivered for each trainee with two additional copies which shall form part of the Operation and Maintenance Manuals. The manuals shall include an agenda, defined objectives for each course.

4.3 Training Schedule

- 4.3.1 A training schedule, together with the name and background of the person who will perform the training, shall be submitted to the Engineer for approval.
- 4.3.2 The training shall include operator training and technical/maintenance training.
- 4.3.3 The program for the training shall include instruction for at least one day instruction on-site.
- 4.3.4 The schedule shall at a minimum cover the following:
 - a) General system overview
 - b) Functional operation of the system i.e.:

- i) System start-up and shut-down procedures
- ii) Equipment operation
- iii) System access requirements
- iv) Alarms
- v) Fault Finding
- vi) Backup Power Procedure (if applicable)
- vii) Incident Reporting
- c) Maintenance
- d) Maintenance Schedule
- e) Standard Maintenance Procedures
- f) Spare Part Lists

4.3.5 Upon completion of the course, the operators should be fully proficient in the system operation and have no unanswered questions regarding the system.

4.4 Operations Training

4.4.1 This training shall be designed to teach operators how to operate the Electrical, Instrumentation and Control systems and shall include the following when applicable:

- a) Start-up, shut-down and operating instruction for all operational modes for the works shall be provided. This shall be comprehensive and shall include actions to be taken in the case of all alarm conditions and basic fault finding.
- b) A layout drawing of the installation, a process flow diagram, and a P&ID shall be provided for each Operator. The instructions described in (4.4.1a) above shall also be provided in printed form for each operator.
- c) If a SCADA and Telemetry system is part of the control system the SCADA operations training as described in the SCADA and Telemetry standard specification shall be incorporated in the training.

4.5 Maintenance Training

4.5.1 This training shall be designed to teach maintenance personnel how to repair and maintain the electrical, instrumentation and control systems and shall include the following where applicable:

- a) Control system software instruction.
- b) Where and how to install spare parts.
- c) Detail list of where to obtain spare parts locally.
- d) Detailed overview of 11 kV protection and switchgear settings
- e) Training on setting of 11 kV protection.
- f) Motor protection relay and settings
- g) Overview of PLC programming for the purposes of making changes and re-loading programs if PLC's are replaced.
- h) If a SCADA and Telemetry system is part of the control system the SCADA maintenance training as described in the SCADA and Telemetry standard specification shall be incorporated in the training.



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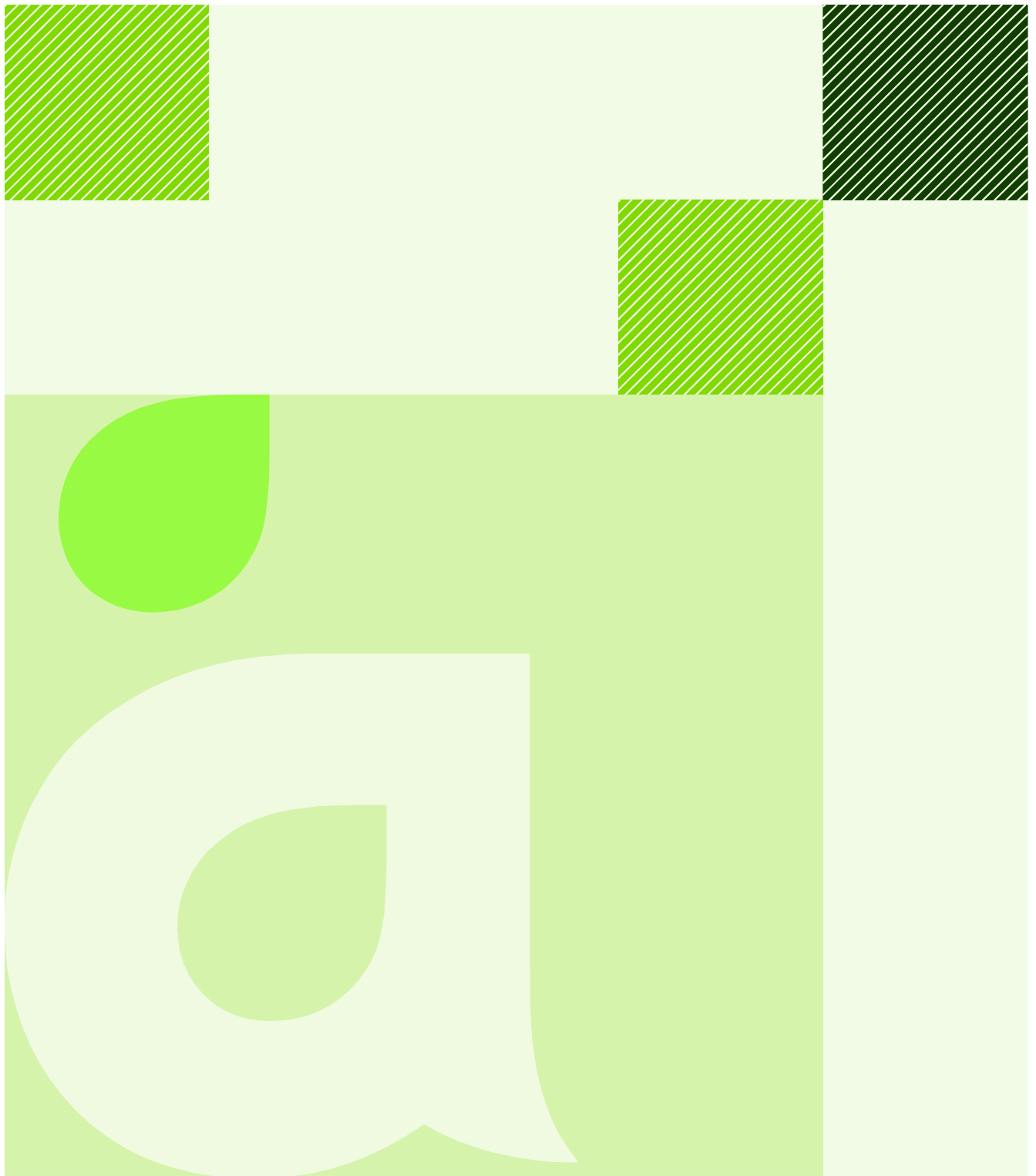
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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification defines the general requirements for the design drawings and documentation, inspections, testing, commissioning, training, as-built drawings and O&M manuals.
- 1.1.2 This Standard Specification covers the materials, components and installation requirements for lightning protection systems for structures to provide protection measures to reduce:
 - a) Injury of living beings by electric shock
 - b) Physical damage to structures to be protected
- 1.1.3 General standard requirements are dealt with in this specification. Detailed documents and drawings requirements for each subsection of the installation are covered separately under each standard specification, relating specifically to the drawings and documents relevant to the field concerned.
- 1.1.4 Further project specific requirements are dealt with in the Contract Document.

1.2 General Requirements

- 1.2.1 All drawings, information and documentation shall be in English and each item shall be identified with the Employer's name and project / scheme / contract reference title and numbers, the Engineer's name and reference numbers and the Manufacturer's works / contract / order references.

2. DESIGN DOCUMENTS AND DRAWINGS

2.1 General

- 2.1.1 This includes all drawings and designs the Contractor must submit during the outset of the Contract for approval by the Engineer.

2.2 General

- 2.2.1 All drawings, wiring diagrams, information, and documentation shall be in English, and each item shall be identified with:
- a) the Client's name and contact details
 - b) Client's project / scheme / contract reference title and numbers
 - c) the Engineer's name and contact details
 - d) Engineers reference numbers
 - e) Contractor's works / contract / order references
- 2.2.2 Drawings for acceptance shall be provided on A4 or A3 paper copies as specified.

2.3 Drawings for Approval by the Engineer

- 2.3.1 The following documentation and drawings shall be submitted to the Engineer for comment and approval prior to the procurement or manufacturing of equipment and assemblies:
- a) General arrangement drawings, typical component mounting plate layouts, and foundation plans of the different equipment to be installed under this contract.
 - b) The internal construction and general arrangement of the different equipment to be installed under this contract.
 - c) Wiring schematic diagrams showing all equipment and components incorporated into the assemblies. Known circuitry outside of the assembly and connected to it, shall also be shown on all drawings. Drawings shall be cross-referenced using a grid / line reference system.
 - d) Software and configuration documentation; including logic diagrams and function block diagrams. The documentation shall be complete and annotated with purpose, function, duty, cross-references, and descriptions, etc.; sufficient to guide an unfamiliar person through the operation of the software.
 - e) Control system function design specification (FDS)
 - f) A detailed parts list containing all components of the different equipment that will be installed under this contract. This parts list shall contain detail such as serial numbers, supplier detail, etc.
- 2.3.2 The following documentation and drawings shall be submitted to the Engineer prior to the installation of cables and wireways and before civil construction have started on the areas where cable routes are required:
- a) Cable route layout drawings showing types of wireways, trenching and cable junction boxes.
- 2.3.3 Manufacturing drawings for approval shall be provided on A3 paper copies and printable electronic format (PDF). No manufacturing shall proceed without the approval of the drawings.

3. OPERATION AND MAINTENANCE MANUALS

3.1 Submission of manuals

- 3.1.1 One copy of the draft manual and spare parts list shall be provided at an agreed date; in advance of the date of the start of the final testing and commissioning on site, for acceptance by the Engineer. If the manual does not comply with this specification, the Contractor shall correct it and re-submit it for approval. At each submission, the Contractor shall provide a duplicate copy for the Employer.
- 3.1.2 Six copies of the final edition, as approved by the Engineer, shall be provided to the Engineer by an agreed date before successful completion of final testing and commissioning.

3.2 General

The Manual shall comply with the following:

- a) The manual shall be for the complete Works.
- b) The manual shall be in English and shall be practically and neatly presented, with an index page up front.
- c) One manual shall contain original documents and this set shall be marked "Original".
- d) The other 5 manuals shall contain all the information in the original and shall be marked "Copy 2" to "Copy 6".
- e) The manual format shall be A4 size with layout suitable for binding in A4 Level Arch type files. Drawings shall be A4 or A3 suitably folded to fit the A4 Lever Arch file.
- f) Binders shall have hard backed, plastic protected covers utilising four-ring, spring-clip holders. Each binder shall not be more than two-thirds full. A title label shall be affixed to the spine of each binder.
- g) The title label in the spine and on the front page shall indicate Contract number, title, Contractor's name, Site/Plant name, Employer name, Employer logo, volume number and contents.
- h) Sections and sub-sections shall be titled, uniquely numbered and provided with separator sheets.
- i) Manufacturer's printed matter shall be marked up to identify the model provided.
- j) Drawings shall be to a scale which makes details clear. Large drawings shall be held in plastic envelopes in the manual. A4 and A3 drawings may be bound as normal pages. Drawings shall also be provided on electronic data storage in AutoCAD, or equivalent, format.
- k) Cross-referencing within the manual is acceptable if this will avoid duplication.
- l) The complete manual shall be provided in pdf format.

3.3 Contents

- 3.3.1 Manuals should contain all the relevant literature, drawings, schedules of installed equipment, procedures, write-ups, type and routine test certificates, etc. which are applicable on the installed equipment and material.
- 3.3.2 The manual shall include at least the following:
- a) All design drawings and documentation relating to the Works; as delivered and tested.

- b) 'As Built' records showing verification against stated design and installation criteria, including a schedule of all the final settings for all user adjustable equipment and components, and copies of all documentation presented and completed during the FATs, the SATs, and any other specified tests on completion.
- c) Schedules of plant and equipment for each enclosure/ junction box / circuit; including a listing of the applicable standards, manufacturer, settings, type number, re-order code, etc., for each item of equipment and component included within each portion of equipment installed.
- d) Manufacturers' contact details, technical information sheets for all items of equipment and components included within the installation. Manufacturers' catalogues may be provided subject to clear identification of the relevant components. All individual manufacturers' equipment / component test certificates and certificates of conformity, shall be included.
- e) Inspection, testing, and maintenance recommendations, including detailed and specific operation, maintenance, and diagnostic data, process for fault-finding and safe isolation information suitable for use by maintenance personnel, shall be provided for all equipment, components, and systems incorporated into the installation.
- f) Schedule of spares provided with the installation, including manufacturer, description, part number, order code, and quantity. A separate list shall also be included showing the manufacturer's recommended list of spare to be kept by the Employer.
- g) A DVD with all software backups and program code used on all data control devices (i.e. PLC, HMI, SCADA, control panels, industrial networks).

3.3.3 The manual shall include detailed descriptions for use by the Client, on how the controlled plant and its management systems are intended to operate and be operated; under both manual and automatic control. Clear and detailed descriptions for each section of the installation shall be provided; and shall include system objectives, controlled plant start-up and shut-down procedures, automatic control, manual intervention, primary and secondary control routines, plant selection including duty and standby options, local and remote selections, operational and safety constraints, status information, alarms and control interfaces with SCADA / telemetry systems, fault routines, etc.

3.3.4 The manual shall include 'as-installed and tested' information on both the hardware and software for each programmable device incorporated within the electrical and electronic panels, including:

- a) Overview of system operation in relation to the controlled plant.
- b) System configuration.
- c) Manufacturers' literature on operation, maintenance and testing of hardware and ancillaries, programming instructions, and diagnostics.
- d) Hard copy program; with listings fully documented.
- e) Listing of the final settings of all process dependent variables.
- f) Permanent back-up copies, licensed in the name of the Client, shall be provided for all software, including operating programmes, application programs, and configuration software for all configurable devices.
- g) Any interconnecting leads, protocol conversion modules, connectors, etc. necessary to connect and communicate with each programmable / configurable device to a standard portable Notebook.

3.4 Composition

The Manual shall comply in general with the format below but modified to suit the Works:

Table 1: O&M Manual Format

NO	HEADING	CONTENT
1.	General	
1.1.	Contents List	Contents list for complete Manual.
1.2.	Description of the Works	Description of the equipment installation with layout drawings and process flow diagrams. Process description and performance parameters for the Works.
1.3.	Equipment List	List of the make, model, operating range and hazardous zoning of every item of mechanical, electrical, instrumentation and control equipment.
1.4.	Drawing List	List of the Contractor's drawings.
2.	General	
2.1.	Operating System	<p>Description of the operating system containing:</p> <ul style="list-style-type: none"> – Start-up, adjustment, operating and shut-down procedures for manual and automatic operation – Emergency operating procedures – Power outage operating procedures – Process verification – Settings, setpoints, protection, alarms and trips. <p>This document shall be suitable for using as a Training Manual.</p>
2.2.	Commissioning	Commissioning results.
3.	Maintenance Schedule	
3.1.	Maintenance and Lubrication	Schedule of routine maintenance for all mechanical, electrical, instrumentation and control equipment, broken down in daily, weekly, monthly, annual periods, etc. The schedule shall be all-inclusive but may refer to manufacturer's standard manuals in other parts of the Manual. The schedule shall include all lubrication periods, lubricants and capacities.
3.2.	Spare list	A schedule of spares that was supplied under the Contract, as well as a list of spare that should be kept by the Employer and where each item can be obtained (part numbers, telephone contact numbers, etc.)
4.	Electrical Equipment	
4.1.	Elec. Equip. Item 1 (e.g. MCC Panels)	<ul style="list-style-type: none"> – Control and electrical details, including logic sequence, circuit diagrams and software, as applicable – Electrical reticulation drawings – Equipment overall dimensions – Wiring diagrams switchboard layout drawings – SLDs.
4.2.	Elec. Equip. (e.g. VFCs)	ditto
4.3.	etc.	ditto
5.	Instrumentation Equipment	
5.1.	Instrumentation Equip. Item 1 (e.g. Magflo)	<ul style="list-style-type: none"> – Circuit diagrams of instrumentation systems and of individual instruments – Installation arrangement (loop diagrams, hook up diagrams) – Normal operating range – Calibration procedures
5.2.	Equip. Item 2 (e.g. level)	ditto

NO	HEADING	CONTENT
6.	Control	
6.1.	Identifying Information	Make and model of PLCs, transmitters, HMIs, computers, etc.; copied from the Equipment List.
6.2.	I/O List	Cross-referenced listing of all I/Os used.
6.3.	SCADA	Colour prints of SCADA mimic screens, control faceplates, sequences and trend screens. Schedule of alarm messages and TAG lists. File structures, lists and naming conventions.
6.4.	Program	An annotated program listing. CDs containing all software. Loop and logic diagrams for each PLC. System control diagram and logic sequence chart.
6.5.	Documents	Schedule of cable terminals. Copy of SCADA hardware diagnostic mimic.
7.	Documents	
7.1.	Drawings	All as-built Contractor's drawings, including MFDs, P&IDs, electrical panel construction drawings, etc.
7.2.	Cable Schedule and cable block diagrams	Cable schedule for power, data, control and instrumentation cables. This shall include the cable construction, conductor material, insulation, protection, voltage rating, start and finish points, route length, duty, load, voltage drop, core area, no. of cores, no. of cores used and gland size. For cable voltages above 400 Volts, the schedule shall also include the purchase details, specification and date of manufacture.
7.3.	Other	List of spares provided in terms of this Contract -Certificate of electrical compliance -Corrosion protection systems used -Coating supplier's data sheets and coating repair procedures.

4. FINAL DOCUMENTATION

4.1 Testing Documentation and Reports

- 4.1.1 A factory acceptance test (FAT) document shall be provided to the Engineer prior to the witnessed FAT. This documentation shall show the manufacturer's in-house test procedures and results for all items of equipment, components, hardware, and software. The document shall show hardware checks, the software simulation procedures, and their combined functional testing. It shall comprehensively and clearly show the test results of the in-house testing. The subsequent report of the FAT witnessed by the Engineer shall be appended to the contractual documentation.
- 4.1.2 The Contractor shall provide his own testing report template to document the FAT witnessed by the Engineer. This shall be to the satisfaction of the Engineer.
- 4.1.3 A site acceptance test (SAT) document shall be produced, which shall detail all tests necessary to demonstrate the functionality of the equipment following its final erection on site. This shall include details of tests and checks on all circuits disconnected for shipping, together with any equipment, components, wiring, or software altered or incorporated into the equipment; following the completion of the witnessed FATs.
- 4.1.4 All drawings, schedules, listings, and other design documentation for acceptance shall be supplied as a comprehensive and integrated package and collated into folders; unless otherwise agreed with the Engineer. Three copies of appropriate documentation shall be submitted on each occasion that agreement is sought.
- 4.1.5 The FAT, SAT, and SIT shall each have been submitted and agreed with the Engineer, prior to the commencement of final testing and site commissioning.

4.2 As-built drawings

- 4.2.1 Detailed "as-built" drawings, clearly labelled as such, and consisting of 3 sets of drawings printed to their original size, and, where the original drawings were larger than A3, 3 sets of drawings printed (with reduced scaling, but without omitting any information from the printed area), to A3, shall be provided by the Contractor, indicating positions of the following:
 - a) Equipment (e.g. light fittings, draw boxes, outlets etc.)
 - b) Wireways (e.g. trenches, conduit, cables ladder/trays, power skirting etc.); and
 - c) Cable routes (including any cable joints)
 - d) General arrangement drawings
 - e) Single Line Diagrams
- 4.2.2 All drawings and schematics shall have been generated by a computer aided design (CAD) package (handwritten documents will not be accepted). The drawings and schematics shall be (where applicable) to scale and must be formatted and styled in accordance to the client and/or Engineer's requirements (with regards to title blocks, text heights, drawing names, etc.). A DVD containing these files, in both CAD and printable document (pdf) format, as well as any and all available electronic versions of relevant data sheets etc. must also be handed over to the Engineer.
- 4.2.3 These drawings need to be approved by the Engineer prior to completion of the Works.



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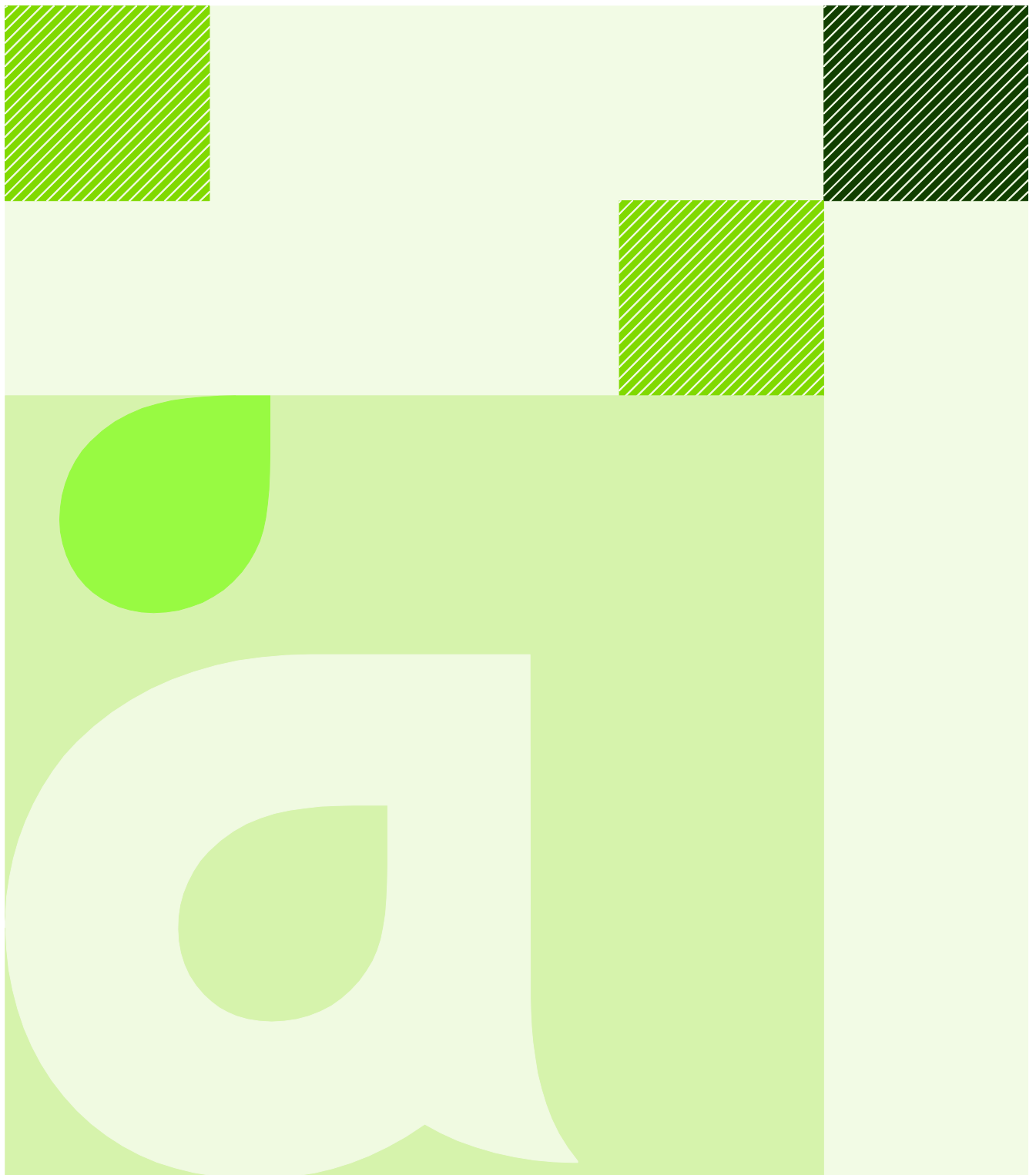
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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification defines the requirements for the design, construction, installation, inspection, testing and commissioning of LV switchgear and controlgear assemblies (Assemblies), including distribution boards (DBs), motor control centres (MCCs), single standalone motor starters or controllers, control panels (either standalone or forming an integral part of the Assembly), control desks and consoles. Where this type of electrical equipment is incorporated within a plant supply package, the provisions of this Specification shall also apply.

1.2 General Requirements

- 1.2.1 An Assembly shall incorporate all components and equipment necessary to achieve the functionality defined in the Project Specification.
- 1.2.2 All materials, components, and equipment used in the manufacture of the Assembly shall be new and unused, shall be of current manufacture, and shall be free from any defects or imperfections.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification contains standard amendments and requirements which shall be applied to the referenced statutory and national standards. The project-specific requirements are provided in the Project Specification, which shall be read in conjunction with this Specification.
- 2.1.2 The design, construction, installation, inspection, testing and commissioning of the Assembly shall comply with all relevant statutory regulations, and the latest editions (current at the time of Tender) of all relevant South African National Standards.
- 2.1.3 The manufacturer shall operate an approved, auditable quality assurance system covering the design, construction, inspection and testing of the Assembly.

2.2 Statutory Requirements

- 2.2.1 The Assembly as manufactured, and as installed on site, shall comply with the following:
- a) Occupational Health and Safety Act of 1993
 - b) Manufacturer's specifications and installation instructions

2.3 Reference Standards

- 2.3.1 The Assembly and all its constituent components and equipment shall comply with the latest published edition of all relevant national standards, including the following:

Table 1: Reference Standards

Standard Number	Description
SANS 152	Low-voltage air-break switches, air-break disconnectors, air-break switch-disconnectors, and fuse-combination units
SANS 156	Moulded case circuit-breakers
SANS 172	Low Voltage Fuses
SANS 1091	National colour standards for paint
SANS 1973	Low-voltage switchgear and controlgear Assemblies
SANS 9000	Quality management systems
SANS 10108	The classification of hazardous locations and the selection of apparatus for use in such locations
SANS 10142	Standard Regulations for Wiring of Premises.
SANS 60044	Instrument Transformers
SANS 60204	Safety of machinery. Electrical equipment of machines.
SANS 60269	Low-voltage fuses.
SANS 60439	Low-voltage switchgear and controlgear assemblies
SANS 60529	Degrees of protection provided by enclosures (IP Code)
SANS 61558	Isolating transformers and safety isolating transformers.
SANS 60947	Low-voltage switchgear and controlgear
SANS 61000	Electromagnetic compatibility (EMC)
SANS 61643-1	Low-voltage surge protective devices Part 1: Surge protective devices connected to low-voltage power distribution systems

3. CONSTRUCTION REQUIREMENTS

3.1 General

- 3.1.1 Assemblies shall be designed and constructed to facilitate inspection, cleaning, repair and maintenance and to ensure absolute safety during operation, inspection and maintenance.
- 3.1.2 The arrangement of all circuit components / functional units shall be to the approval of the Engineer.
- 3.1.3 Where detailed in the Project Specification, spare compartments of a given size shall be provided within the enclosure. Each shall be equipped with a plain (i.e. un-punched) opening compartment door.
- 3.1.4 Every spare compartment shall be sized to house a triple pole and neutral incoming short circuit protective and isolating device, and shall be provided with a compartment earthing terminal.
- 3.1.5 Every spare compartment shall be provided with a gland plate or have access to an existing cable way within the enclosure.

3.2 Enclosures

- 3.2.1 All conductors and terminals that form part of the Assembly, including earth conductors and the Assembly earth bar, shall be enclosed within it. An earth stud may be provided as a part of a cable glanding facility.
- 3.2.2 Assemblies shall be constructed of materials capable of withstanding the mechanical, electrical and thermal stresses to which it may be subjected and the environmental and operating conditions likely to be encountered in normal service.
- 3.2.3 All boards, panels and cubicles shall be vermin and dust proof and the minimum degree of protection shall be:

Table 2: Minimum levels of ingress protection

Location	Description	Minimum rating
Indoor	Clean, dry areas (e.g. inside substations or motor control rooms)	IP44 (doors closed)
		IP2X (inter-compartment & doors open)
Outdoor	Located outside buildings	IP65 (doors closed)
		IP2X (inter-compartment & doors open)

- 3.2.4 Where heat is generated within the enclosure, it shall, where possible, be designed to dissipate naturally from the enclosure surface. Where this is not possible, ventilation openings shall be provided that maintain the highest practicable IP rating of the enclosure, subject to a minimum of IP42. Where cooling air is drawn into the enclosure, dust filters shall be provided where practicable.
- 3.2.5 For all variable speed drives and soft-starters (without bypass contactors) installed in indoor Assemblies, mini-extraction fans shall be installed inside the drive compartment to dissipate heat, without compromising the assembly's IP rating.
- 3.2.6 Particular attention shall be given to the ventilation of outdoor mounted boards, to eliminate build-up of excessive heat inside the boards caused by the solar radiation or internal heat generation.
- 3.2.7 Any internal partitions necessary to provide inter-compartmental segregation within the enclosure shall be of the same material as the sides of the enclosure.

3.2.8 All the surfaces of the enclosure, and of its constituent equipment and components shall be suitably protected against the effects of any likely atmospheric corrosion present at the operating location.

3.2.9 Purpose-made gland plates shall be protected against corrosion by electro-plating, galvanising, or be made of stainless steel and shall not be painted.

3.3 Construction of Free-Standing MCCs and DBs

3.3.1 Free-standing MCCs and DBs shall be constructed from steel with a structural frame permanently clad with side plates, so as to provide a multi-compartmented structure that is rigid with all doors and covers removed, and such that it will not deform during transport or installation. The enclosure doors and covers shall themselves be suitably braced so as to be rigid and not deform or flex when fully equipped and handled.

3.3.2 Each compartment formed within the enclosure for the purpose of housing components or equipment shall be provided with dedicated mounting plates for that purpose, which when removed do not expose any other compartment or live parts. Cabling shall only be terminated on or in the enclosure at gland plates provided for that purpose.

3.3.3 Horizontal wireways (top and bottom) shall extend through the width of each section.

3.3.4 The minimum metal thickness of the enclosure's constituent parts shall be as follows:

- a) External cladding : 2 mm
- b) Internal partitions: 1,6 mm
- c) doors and removable panel covers: 2 mm

3.3.5 Free-standing Assemblies shall be mounted on and bolted to a rigid hot-dip galvanised steel 100 x 50 x 6 mm channel base.


3.3.6 The maximum height of any Assembly (including its base) shall be 2100 mm above finished floor level. No equipment other than busbars and/or inter panel control wiring shall be installed higher than 1900 mm above finished floor height, neither shall any equipment, other than cable glands and inter panel control wiring be installed lower than 300 mm above finished floor level.

3.3.7 Compartment single doors shall have vertical hinges mounted on their left hand side, and all doors shall have an angle of opening that is limited to 95 degrees. Where specifically agreed with the Engineer, a compartment single door on a front access only Assembly may be hinged on the right hand side if this will reduce the number of dropper / cable way chambers required. Wide compartments with dual doors shall open in wardrobe style, such that the second door is interlocked with the first.

3.3.8 Any cover which is required to be removed for adjustment, access, or maintenance and exceeds 0.75 m² in area, shall be provided with supporting lips, lift-off hinges, locating dowels, or handles, in order to facilitate safe removal and replacement.

3.3.9 Doors and any covers shall be fixed to the enclosure using captive bolt type fasteners, and each hinged door shall be capable of being removed, following disconnection of the electrical and earthing connections. Compartment doors shall be provided with securing catches which can be locked with a padlock, as follows:

- a) door ≤ 400 mm high 1 No.
- b) door > 400 mm high 2 No.
- c) door > 1200 mm high 3 No.

- 
- 3.3.10 The Assembly shall be constructed for front and rear access unless otherwise specified in the Project Specification. Where the Assembly shall be designed for front access only it shall be possible to gain access to every component, item of equipment, busbar and cable from the front (or for busbars, the top) of the enclosure; whether for maintenance or for replacement.
- 3.3.11 The form of internal separation (in accordance with SANS 60439-1) shall be as specified in the Project Specification. Form 3b or 4a as appropriate, shall be considered the minimum allowable internal separation for MDBs and MCCs.
- 3.3.12 Any apertures between compartments (including busbar compartments) through which the copper-work or cabling passes, shall be effectively closed off to minimise the possibility of an arc fault propagating between compartments.
- 3.3.13 Fixings for components, component mounting plates, etc. shall not penetrate another compartment containing live parts. Where self-tapping screws are used for component fixing they shall be of the thread forming or thread rolling type. Components, wiring, labelling, etc., shall only be located within compartments on a removable mounting plate, and in such a manner that facilitates easy inspection, maintenance, or removal and replacement, and without necessitating the removal or dismantling of any other components or wiring, or the use of special tools.
- 3.3.14 Unless detailed otherwise specified in the Project Specification, the Assembly shall be constructed so as to facilitate future extension by the addition of extra full height sections at either end. To accommodate this, any covers, fixings, etc. shall be flush with the end faces of the enclosure, and the end sections of busbars and earth bars shall be prepared for future extension.
- 3.3.15 The Assembly shall be constructed so as to permit it being split into sections in order to facilitate transportation and subsequent site erection. Each transportable section shall be labelled as to its shipping weight, shall be equipped with lifting eyes, which shall be removed on completion of the site erection.
- 3.3.16 All Assemblies shall have at least 15 % spare unequipped space complete with busbars, partitioning into compartments, etc. for future extensions.

3.4 Power distribution within an Assembly

- 3.4.1 The power distribution and circuit protective arrangements within an Assembly shall be designed so as to co-ordinate with the characteristics of the electrical system(s) connected to the incoming terminals of the Assembly, including emergency or temporary supplies and specifically noting the following:
- a) maximum prospective RMS short circuit current from all simultaneously available sources of supply, together with any fault contribution from large motors directly connected to the Assembly
 - b) type of system earthing (i.e. TN-S, TT, etc.), the maximum available earth fault current, and the maximum earth fault loop impedance
 - c) up-stream protective device ratings and settings
- 3.4.2 Where this information is not stated in the Project Specification, it shall be obtained from the Engineer before the design of the Assembly commences.
- 3.4.3 Where the maximum prospective RMS short circuit current from all simultaneously available sources of supply, together with any fault contribution from large directly- connected motors, exceeds 10kA, the Assembly a Type Tested Assembly with stated deviations in compliance with SANS 1973-1.

- 3.4.4 Where the maximum prospective RMS short circuit current is 10kA or less, the Assembly shall comply with the requirements of SANS 1973-3.

3.5 Functional unit short-circuit protection and isolation

- 3.5.1 The Assembly shall be provided with separate incoming isolation for every electrical power system (including emergency or temporary supplies) connected to it.
- 3.5.2 The connection from the Assembly power distribution system into every compartment shall be terminated on a short circuit protection device, which may also incorporate a compartment isolating device, for short-circuit protection of all the components within a functional unit.
- 3.5.3 Every motor starter compartment shall be provided with a door interlocked isolation device, which shall isolate all sources of supply that enter the motor starter compartment. Where a functional unit; e.g. a motor starter, etc., comprises a group of interlocked compartments, the isolation device shall be located in the compartment receiving the supply.
- 3.5.4 Every compartment containing a distribution board or low voltage transformer shall be provided with an isolation device, which may be located in an adjacent compartment. For some compartments housing power monitoring equipment or instrumentation and process control equipment, it may be appropriate to provide a means of isolation within the compartment.
- 3.5.5 Unless separate fuses are used as the short circuit protection device, the isolation device and short circuit protection device shall be combined. Fuses may only be used to limit fault currents if approved by the Engineer.
- 3.5.6 Separate isolating devices shall be switch-disconnectors suitable for on-load switching. They shall be capable of being padlocked in the isolated / 'off' position at the compartment door, and at the isolating mechanism with the compartment door open. Any isolator mechanism extension shafts shall be provided with guide brackets as necessary to prevent excessive shaft deflection.
- 3.5.7 The compartment door shall be mechanically interlocked such that it shall not be possible to open the door when the isolating device is in the 'on' / 'closed' position or when the operating handle is padlocked in the 'off' / 'open' position. Where the means of isolation is only accessible from within the compartment, it shall be protected to a level of IP2X.
- 3.5.8 The following types of devices may be used:
- a) Air circuit breaker (ACB) or moulded case circuit breaker (MCCB)
 - b) Fuse switch-disconnector
 - c) Switch-disconnector with separate fuses
- 3.5.9 All field circuits connected to a functional unit (e.g. valve actuators, limit switches, etc.) shall be provided with isolation either by or within that functional unit.
- 3.5.10 Where safety interlock keys are provided, e.g. to control device operation or to restrict access, they shall only be released in the safe condition, and shall be unique across that Assembly and any other Assembly installed at the same site.


4. ELECTRICAL COMPONENTS

4.1 Circuit Breakers (CBs)

- 4.1.1 Circuit breakers shall be either air circuit breakers (ACBs) or moulded case circuit breakers (MCCBs), as indicated on the single-line diagram for the Assembly.
- 4.1.2 CBs shall have a rated service short-circuit breaking capacity not less than that of the maximum prospective fault current at the point of connection in the power system, which shall be taken to be the busbar rated short-time withstand current specified for the Assembly. Incomer CBs shall have a rated short-time withstand current and time not less than that of the busbars.
- 4.1.3 CBs with rated currents over 100 A shall have built-in protection, that will discriminate with both up-stream and down-stream protective devices, as appropriate to the application.
- 4.1.4 ACBs for incomer and feeder applications shall be fitted with adjustable electronic protection. MCCBs for incomer applications shall be fitted with adjustable thermal-magnetic or adjustable electronic protection.
- 4.1.5 An ACB shall incorporate padlockable cover(s) to permit the securing of the open, close, and trip actuators against inadvertent or unauthorised manual operation.
- 4.1.6 Where an ACB or MCCB has electrically operated control circuits; e.g. opening, closing, tripping, spring charging, indication, etc., they shall be provided with individual fuse or MCB protection.
- 4.1.7 All ACBs and selected MCCBs (as indicated on the single-line diagrams) shall be of a withdrawable pattern with the number of poles indicated on the single-line diagram.
- 4.1.8 A withdrawable ACB or MCCB shall be provided with clearly visible carriage position indication (connected/disconnected/test), and shall be capable of being locked in each position. Mechanical interlocks shall be provided that only permit movement of the carriage whilst the main circuit contacts are in the 'OFF' position. It shall be possible to test the control circuits of an ACB with it partially or fully withdrawn.
- 4.1.9 As a withdrawable ACB or MCCB is being withdrawn, padlockable safety shutters shall automatically cover over the supply side and the load side fixed connections. These shutters shall be capable of independently being opened for testing purposes.
- 4.1.10 One (only) handling truck shall be provided suitable for each type of withdrawable ACB or MCCB supplied as a part of the Assembly, or as a part of any other Assembly supplied to the same building housing the Assembly.
- 4.1.11 Special maintenance tools, where required, shall be provided with each breaker.
- 4.1.12 Cables connected directly to CB terminals will generally not be permitted. Adequately sized cable/busbar adapters shall be provided.

4.2 Switch-disconnectors

- 4.2.1 The switch shall be suitable for the continuous rated duty of the circuit it controls.
- 4.2.2 The utilisation category of the switch-disconnector shall be AC23 for motor switching duties, and AC22 for switching of mixed resistive and inductive loads, with an appropriate utilization category (A for frequent switching and B for infrequent switching).

- 
- 4.2.3 Rotary switch-disconnectors shall be provided with a 'break-before-make' operation for each pole. The rotary switch, or changeover switch formed by the proprietary interlocked interconnection of two switch-disconnectors or fuse switches, shall incorporate a centre 'off' position.
- 4.2.4 Switch-disconnectors for motor starter or variable speed drive duties, that incorporate a test position, shall enable the control circuit supplies while ensuring isolation of the main supply.

4.3 Fuse switches

- 4.3.1 Fuses and fuse bases shall comply with the requirements of SANS 172, and shall be provided with an indicating device to show the "blown" state of the fuse.
- 4.3.2 Only Motor circuit fuse links as defined in BS 88 shall be permitted on motor starting circuits.
- 4.3.3 Fuse current ratings shall be indicated on engraved 20 x 12 mm white-black-white traffolyte labels in 4 mm figures. The labels are to be fitted at the fuse bases and shall not be obscured by wiring.
- 4.3.4 This shall comprise a moulded carriage accommodating either HRC fuses or solid links, and shall provide for a switched neutral where required.
- 4.3.5 Provision shall be made for the following:
- a) Double break contacts on each pole.
 - b) Arc barriers on each pole.
 - c) IP2X protection in either state.
 - d) Silver plated copper contacts.
 - e) Neutral link where required.
 - f) Mechanically operated ON/OFF indicator.
 - g) Auxiliary switch facility.
 - h) Full interchangeability of equivalent rated units
- 4.3.6 The continuous thermal rating and the circuit fuse rating shall be indicated adjacent to the switch.
- 4.3.7 The minimum utilisation category of the fuse switch shall be AC23 for motor starting duties, and AC22 for power distribution only duties.
- 4.3.8 All fuses used on LV circuits shall be HRC cartridge type fuse links complying with both SANS 60269 and BS 88 Part 6 / BS 88 Part 2 Section 2.2 (fuse links with bolted connections), except as follows:
- a) semiconductor protection fuses recommended or provided by the manufacturer of any power electronics incorporated into the Assembly;
 - b) sub-distribution fuses for extra-low voltage control circuits in ICA equipment compartments.
- 4.3.9 The sub-distribution fuses for control circuits (mentioned above) shall be miniature ceramic cartridge fuses complying with BS 2950. They shall be mounted in knife-edge ('swinging blade') disconnect type DIN rail mounted terminals. Knife-edge disconnect type terminals shall similarly be used for neutral links.
- 4.3.10 Neutral and earth link holders shall be non-interchangeable with fuse holders, and fuse and link holders shall be segregated according to circuit voltage.

- 4.3.11 Where HRC cartridge type fuse links do not form an integral part of an item of equipment such as an enclosed transformer, a fuse switch, etc., they shall be mounted in all-insulated fuse carriers fitted into fuse holders. An associated neutral circuit shall be provided with a solid copper link, which shall be mounted in an identical manner adjacent to the phase circuit fuse holders.
- 4.3.12 Fuse and link bases shall contain insulating shrouds, that can only be removed using a tool. A fuse or link shall only be capable of insertion into its base using the appropriate carrier. Fuse and link carriers and holders shall be coloured as follows:
- a) fuse links: black
 - b) neutral links: white
 - c) earth links: green
- 4.3.13 A spare set of all fuse types and ratings used within a functional unit shall be mounted within each functional unit.
- 4.3.14 Combination fuse switches shall comply with SANS 152 and shall be of the independent manual operation type and shall afford minimum protection of IP21.

4.4 Switch operator

- 4.4.1 Switch operating mechanisms shall include operators for fuse switches, switch-disconnectors, moulded case circuit breakers and motor protection circuit breakers for Assemblies.
- 4.4.2 Switch operating mechanisms shall be door mounted and the switches shall be fixed mounting.
- 4.4.3 Switch operating mechanisms shall positively engage with the switch shaft when the door is fully closed and shall be so interlocked with the door so that:
- a) It shall not be possible to gain access via a cover or door to any live points unless the switch is in the open position.
 - b) It shall not be possible to re-close the door or cover unless the switch is in the open position. Operation of the switch with the door open is permissible.
- 4.4.4 Clear indication shall be given, both with the access cover or door open or closed, as to whether the switch is in the open or closed position. Colour indication alone will not be acceptable.
- 4.4.5 Operating handles shall be pad lockable in the “off” / “open” position. The mechanisms shall accept not less than two padlocks each having a shackle diameter of 6 mm.
- 4.4.6 Any isolator mechanism extension shafts shall be provided with guide brackets as necessary to prevent excessive shaft deflection.

4.5 Contactors, Relays and Timers

- 4.5.1 Contactors and relays shall be selected so as to be suitable for the foreseeable operating duty (utilisation category) and operational frequency. They shall operate reliably under reduced voltage conditions by closing (i.e. pulling in and holding) at 85 %, and remaining closed at 60 %, of the rated coil voltage, and shall be suitable for continuous operation at 110 % of the rated coil voltage.
- 4.5.2 Contactors shall comply with SANS 60947-4-1, and shall be electro-magnetically operated air-break multi-pole block type construction. They shall readily accept a wide variety and configuration of auxiliary contact blocks, which shall have their terminals protected to IP2X.

- 4.5.3 Relays and timers shall be totally enclosed plug-in devices. The bases shall be keyed in order to differentiate between differing relays and timers, and their differing coil / electronics operating voltages, and to prevent incorrect insertion. Bases shall be fitted with retaining clips, and each relay / timer shall have its pin configuration printed on the side of its casing.
- 4.5.4 Relay / timer bases shall have screw clamp type terminals protected to IP2X, which shall be accessible with a screwdriver whilst the relay / timer is plugged in.
- 4.5.5 Relays shall be provided with a transparent enclosure, visual indication that the relay is in the energised and closed state, and a manual test button.
- 4.5.6 Timers shall operate electronically or be synchronously driven, and shall be provided with linearly calibrated time interval scales. The smallest indicated time interval shall be 10 % (or less) of full scale, with a repeatability of 1 % (or better) of full scale. Timers shall be provided with 'energised' and 'timed out' indicators.
- 4.5.7 Where timers require to be viewed by operators, they shall be flush front of panel mounted behind a transparent lockable cover.
- 4.5.8 Contactors shall be satisfactorily withstand the thermal and dynamic effects arising from the magnitude and duration of through fault currents dictated by the characteristics of the associated protective devices and shall be selected in accordance with the kW/current rating.
- 4.5.9 Contactors shall be triple-pole electromechanically operated air-break type, held in or latched pattern as specified.
- 4.5.10 Contactors shall be classified as utilisation category AC3 uninterrupted duty for motor starting and as utilisation category AC1 intermittent duty, Class 1, 60 % for heater duty.
- 4.5.11 Contactors shall be fitted with the required auxiliary contacts. These shall be rated at not less than 6 A and shall be positively driven in both directions.
- 4.5.12 Auxiliary relays for control purposes shall be of the multiple pole type and shall preferably possess the feature of field convertible contact configuration.
- 4.5.13 Plug-in type relays shall have:
- a) Positive-acting mechanical retaining clips. Contact friction alone as a retaining method is unacceptable.
 - b) A keyed member on plug and socket sides to prevent incorrect insertion.
 - c) Clear and indelible markings on both the relay and its base indicating the circuit reference in conformity with the associated circuit and connection diagrams.
- 4.5.14 Auxiliary time delay relays shall be of electronic or synchronous motor-driven type and the time setting shall be infinitely adjustable over the range of 5 - 100 % of the maximum delay. Timing relays deriving the delay function by thermal or pneumatic means will not be acceptable.
- 4.5.15 Auxiliary relays shall have a minimum of 4 individual contacts and shall preferably have the facility to add an extension block with an additional four (4) individual contacts.

4.6 Control switches and pushbuttons

- 4.6.1 Control selector switches shall be of a rotary spring loaded type, with an AC11 rating, and shall have clearly identified switch positions. Where switches are lockable, the key shall be held captive in the abnormal or over-ride position.

- 4.6.2 Pushbuttons shall comply with SANS 60947-5-1 and shall be of a 22 mm diameter, flush bezel type.
- 4.6.3 Emergency stop pushbuttons shall be of a mushroom headed push to stop, stay-put and twist-to-release type. Key type release buttons shall not be used.
- 4.6.4 Pushbuttons shall be coloured as follows:

Table 3: Pushbutton colours

Function	Colour
Start	Green
Stop	Red
Reset	Black
Emergency stop	Red
Lamp test	Black
Close / Down	Green (or black)
Open / Up	Green (or white)
On	White (or green)
Off	Black (or white)
Forward	Green (or white)
Reverse	Green (or black)

- 4.6.5 Pushbuttons shall be of the one-hole fixing, oil tight pattern.
- 4.6.6 Operators (and the mating holes) shall be keyed to prevent rotation of the assembly in the panel.
- 4.6.7 Contacts shall be adequately rated for the circuit duty but shall not be less than 10 A, 230 V AC or 120 V DC rating.
- 4.6.8 In addition the operator shall carry an internationally acceptable symbol indicating its function or shall have mounted immediately above it a clear legend of its function or action.
- 4.6.9 Operators initiating a motion or circuit closure shall be flush with the surrounding bezel, while operators stopping a function or opening a circuit shall project beyond the bezel.
- 4.6.10 Operators providing a selective function e.g. local/remote or auto/manual, shall operate in a semi-rotational manner with equal angular displacement about an imaginary vertical centre line.

4.7 Indicating lamps

- 4.7.1 Indicating lamps shall be suitable for use on either 230 V AC or 24 V DC control supplies, and shall be light emitting diode (LED) type. Lamps suitable for use on 230 V AC shall incorporate a step-down transformer. Indicating lamps shall be continuously rated for a voltage of 10 % in excess of the rated voltage.
- 4.7.2 Lamps shall comprise 22 mm diameter units incorporating either a multi-cluster array of LEDs or a single high intensity surge protected LED; replaceable from the front of panel without any special tools.
- 4.7.3 Indicating lamps shall render good visibility under conditions of an ambient illumination level of 400 Lux.
- 4.7.4 Lamps shall be provided with one of two indicator lamp colour coding schemes as follows:
- a) a primary colour coding scheme, in compliance with IEC 60073, or

- b) a secondary colour coding scheme; which although not standard, is required in order to harmonise with existing operational equipment.

4.7.5 Unless detailed otherwise in the Project Specification, the Assembly shall be provided with indicating lamps coloured in accordance with the primary colour coding scheme, which shall be as follows:

Table 4: Primary colour coding scheme

Function	Colour
Dangerous condition	Red
Emergency / hazardous condition	Red
Emergency stop operated	Yellow
Impending critical condition	Yellow
Alarm / abnormal condition	Yellow
Tripped / fault condition	Yellow
Warning	Yellow
Normal condition	Green
On	Green
Running	Green
Closed condition	Green
Mid position / mid travel	Green + White
Open condition	White
Available / auto available	White
General indication / monitoring	White
Mandatory operation required by operator	Blue

- 4.7.6 Where specified in the Project Specification, the manufacturer shall supply an additional number of loose indicating lamps (or their coloured lenses) of a specified type and coloured in accordance with the primary colour coding scheme, and shall retrofit these to specified existing assemblies.
- 4.7.7 Where an Assembly is provided that incorporates lamp colours in accordance with the secondary colour coding scheme, the manufacturer shall also supply an additional quantity of loose indicating lamps. There shall be a sufficient quantity of the required types and colours; coloured in accordance with the primary colour coding scheme, to permit a third party to retrofit them the Assembly at a later date in order to bring it into compliance with the primary colour coding scheme. In addition, the final drawings for the Assembly shall not detail the colour of any indicating lamp that does not comply with the primary colour coding scheme.

4.8 Power measuring instruments and current transformers

- 4.8.1 The Project Specification states which functional units shall be provided with power/current and voltage measuring instruments, the type, and the facilities required.
- 4.8.2 Display instruments used to indicate voltages and currents shall normally be analogue instruments, shall comply with IEC 60051, be of the low-impedance type and have an accuracy class of 1.5. They shall be flush front of panel mounted with a 90° quadrant minimum scale length, and be DIN96 size for power distribution functional units, and DIN96 or 72 sized for motor starter functional units.
- 4.8.3 External zero adjustment shall be possible on all indicating instruments to facilitate adjustment without dismantling the instrument.
- 4.8.4 Instruments shall be scaled to 120 % of the anticipated designed indication. Ammeters shall be provided with compressed scales to accommodate motor starting or other in-rush


currents, and ammeters monitoring motor currents shall be provided with an adjustable red pointer to indicate full load current.

- 4.8.5 Meters and relays shall be capable of withstanding, without damage, the secondary currents associated with the maximum available through fault current.
- 4.8.6 Instruments shall be provided with shrouded connections to their rear, and ammeter circuits with a full scale deflection in excess of 25 A shall be connected via current transformers (CTs). Apart from CT and ammeter circuits, instrument circuits shall be fused.
- 4.8.7 Instruments used in power distribution circuits shall be flush front of panel mounted and shall provide selectable front of panel digital display of at least the following measurements:
- voltage between phases and between phases and neutral
 - current in each phase
 - power (kW)
 - kVA
 - power factor
 - consumption (kWh)
- 4.8.8 They shall provide data output signals for presentation to PLC, SCADA, telemetry, etc.
- 4.8.9 Where the Project Specification indicates that instruments shall provide fieldbus communication with a control system, this shall be via an open protocol compatible with the proposed control system.
- 4.8.10 Run hour meters shall be of a 5 digit minimum non-re-settable odometer type, with visual indication of operation, and a minimum resolution of one hour.
- 4.8.11 Current transformers (CTs) shall be air insulated, shall comply with SANS 60044, and shall have short circuit ratings in excess of those prevailing at the point of connection. They shall bear individual rating plates, which shall clearly identify the winding polarities (primary or secondary), together with the connection details of any multi-ratio windings.
- 4.8.12 Current transformer accuracy classes shall be selected as follows unless otherwise indicated on single-line diagrams:

Table 5: Transformer accuracy classes

Type of circuit	Class	Comments
Indication	3 or 5	To match the % accuracy of the instrument
Measurement	0.5 or 1	To match the % accuracy of the instrument
Motor protection	10P10	Or as required by protection device manufacturer
Power system protection (e.g. IDMTL)	10P20	Or as required by protection device manufacturer
Power system unit protection (high accuracy; e.g. REF, generation, unit protection)	PX	As specified by protection device manufacturer

- 4.8.13 One pole of the secondary winding of each CT (or group of CTs) shall be connected to earth via a link. All connections to the CT secondary winding shall be made via a proprietary shorting terminal test block. Provision shall be made for attaching test links.
- 4.8.14 Current transformers shall be of the low-impedance type and shall, where ratio, class and output requirements permit, preferably be of the ring-type bar-primary design.

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- 4.8.15 Current transformers shall be rated to withstand the thermal and magnetic stress resulting from the maximum available through fault current.
- 4.8.16 Bridging terminals for current transformers shall be provided at the outgoing terminals where external connections are required. In addition, terminal blocks shall be provided to permit secondary injection tests on protective relays.

4.9 Control-circuit and auxiliary supply transformers

- 4.9.1 Voltage transformers shall be designed, constructed and tested in accordance with the requirements of SANS 60044.
- 4.9.2 Voltage adjustment over the range 95 - 105 % of nominal ratio shall be provided by off-circuit tapings.
- 4.9.3 Transformers shall be provided with isolating switches on the HV side and with protection on both the HV and LV sides.
- 4.9.4 Voltage transformer primary and secondary windings shall be protected by fuses.
- 4.9.5 The protection on the HV. side shall be rated sufficient to withstand inrush currents.
- 4.9.6 Control transformers shall be rated as follows:
- a) Sum of sealed-in burden of all contactors, relays, timers and lamps fed from that unit; plus
 - b) Pickup burden of largest Contactor fed from that unit; plus 10 %.
- 4.9.7 The regulation on closing the largest circuit with all the loads except that of the largest load, or if there is more than one, one of the largest loads, imposed on the transformer, shall not exceed 5 %.
- 4.9.8 One side of the transformer secondary winding, or the star point thereof, shall be connected to earth via a removable bolted link.
- 4.9.9 Voltage transformer nameplates shall be fixed in a position so that details can easily be read when fitted in the cubicle.

4.10 Capacitors

- 4.10.1 Capacitors shall be of the non-toxic, dry, self-healing, metallised film type, and comply with SANS 60831.
- 4.10.2 Capacitors shall be fitted with a means of electrical discharge to reduce the residual voltage to less than 60 V within 5 seconds of being switched off.


5. MOTOR STARTER FUNCTIONAL UNITS

5.1 General requirements

- 5.1.1 Motor starter functional units shall be provided as indicated on the single-line diagrams and as detailed in the Project Specification, and all equipment, components, and wiring shall be included to achieve the required functionality. The following methods of motor starting shall be considered, where the selection is the Contractor's responsibility, to provide the required functionality:
- a) direct on line (DOL)
 - b) star/delta (open/closed transition to suit application)
 - c) line reactor
 - d) auto-transformer (closed transition)
 - e) soft starters and variable speed drives using power electronics
- 5.1.2 Where specified in the Project Specification, integral direct on line starters complying with SANS 60947-6-2, shall be used for motor starters of less than 10 kW. The integral motor starter shall incorporate an isolation device, a short circuit protective device, a contactor and overload protection with Type 2 coordination.
- 5.1.3 Each motor starter shall be provided with an isolation and short circuit protection device.
- 5.1.4 Motor starter contactors, short circuit protective devices, and thermal overloads shall be selected so as to provide Type 2 Co-ordination in accordance with SANS 60439-4-1. The minimum starter contactor utilisation category shall be AC3.
- 5.1.5 Motor circuit residual current protection shall only be provided where necessary to discriminate with upstream protection, where the power supply is derived from a TT source, or where specified in the Project Specification.
- 5.1.6 Contactors used where simultaneous closure would be dangerous, e.g. in reversing, star-delta, or closed transition starters, shall be provided with both mechanical and electrical interlocks.
- 5.1.7 Where components with short time ratings are used, e.g. resistors, transformers, etc., they shall be provided with hardwired temperature monitoring circuits, arranged to trip the line contactor if their thermal limits are reached.
- 5.1.8 Withdrawable starters shall be provided with suitable interlocks to prevent chassis withdrawal or insertion when the starter isolation device is in the "on" position.


5.2 Functional requirements

- 5.2.1 Every individual motor starter unit shall include all equipment, components and wiring necessary to safely and reliably operate the driven plant item. It shall be possible to manually operate plant item from the front panel of its functional unit, notwithstanding any failure or de-selection of any automatic control system, networking / communication facility, PLC, SCADA, or telemetry system. In order to achieve this, the appropriate push buttons / keypads and indicators shall be provided front of panel.
- 5.2.2 If the power supply fails whilst a motor is running, the line contactor shall open. On restoration of the power supply, the motor starter shall immediately be made available to re-start the motor without manual attendance or intervention on receipt of a start command (be it initiated manually or automatically). However, where a hardwired automatic control facility is available, a power-on delay timer (adjustable between zero and 60 s) shall be provided in the hardwired circuit.

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- 5.2.3 Where a 'healthy' signal is required, it shall confirm that the functional unit isolation device is closed, the starter control supply is healthy, no fault condition exists, emergency stop(s) are released, the local isolator (where fitted) is closed. The 'healthy' signal shall be used to provide the 'drive available' input signal to any automatic control schemes or automatic duty selection routines.
- 5.2.4 Each functional unit shall provide any automatic control schemes (including auto duty selection routines) with the following status signals as a minimum, as well as all others as specified in the Project Specification:
- a) Manual/auto mode
 - b) Running
 - c) Tripped
 - d) E/Stop activated
- 5.2.5 Each motor starter shall be provided with an emergency stop circuit, which together with its components shall comply with BS EN 418. A field 'twist to reset' emergency stop button shall be provided. On operation of the emergency stop circuit, the motor line contactor shall immediately open, and the emergency stop circuit shall lock out until it is reset. A front of panel 'emergency stop operated' indication lamp and a status signal for PLC monitoring shall be provided. A composite starter may have a common emergency stop circuit controlling all of its constituent drives.
- 5.2.6 Where identified in the Project Specification, specific process or driven plant interlocks shall be hardwired into the motor starter, and when operated, shall stop and inhibit the drive.
- 5.2.7 Front of panel pushbuttons shall be provided for manual start (forward, and where applicable; reverse), and manual stop. A front of panel control selector switches shall be provided for 'Manual / Off / Auto' or 'Remote / Local' as specified in the Project Specification.
- 5.2.8 Front of panel indicator lamps shall be provided for 'running' and 'tripped', and an ammeter shall be provided for motor circuits ; other front of panel indications e.g. specific fault indication lamps , hours run meter, number of starts counter, etc. shall be as specified in the Project Specification.

5.3 Motor protection

- 5.3.1 As a minimum, every motor starter circuit shall be provided with a thermal overload unit connected to monitor the current in each energised winding of the motor. Unless otherwise specified in the Project Specification, motors of over 30 kW shall be provided with electronic overload protection, and motors of over 75 kW shall be provided with electronic motor protection relays. Intelligent multifunction electronic relays shall be provided if specified in the Project Specification.
- 5.3.2 Thermal overloads shall be scaled and adjustable such that the motor rated current is mid-range, and shall provide a temperature compensated thermal element for each supply phase to the motor. The unit shall provide single phasing protection, and incorporate auxiliary tripping contacts with a manual test facility. The unit shall be capable of being manually or automatically reset (set to auto). Unless otherwise specified in the Project Specification, thermal overloads shall be trip class 10.
- 5.3.3 Electronic overload units shall incorporate the features required of a thermal overload, together with provision for the adjustment of tripping and reset times. In addition, stalled rotor protection shall be provided, together with integral thermistor protection where required. Where required, electronic overloads shall be suitable for use in conjunction with power electronics (soft starters or variable frequency converters).
- 5.3.4 Electronic underload protection shall be provided for all centrifugal pump, fan, or directly driven mixer motor circuits above 30 kW. When detecting underload, the device shall



measure the true motor power (and not just the phase angle), shall be configured to detect an unloaded running motor condition, and shall incorporate start delay, motor trip, and manual / auto reset (set to auto) facilities. The unit shall incorporate a digital percentage load display.

- 5.3.5 Where required on drives of less than 30 kW, the underload unit shall be provided with overcurrent protection providing the same facilities as a thermal overload. When required on larger drives, underload protection shall be provided as an integral part of an electronic overload or motor protection relay, and where applicable shall be suitable for use in conjunction with power electronics.
- 5.3.6 Motor thermistor and RTD (PT100) relays shall be provided for motors which have been specified to be fitted with thermistors or RTDs.
- 5.3.7 Motor starter functional units for immersible/submersible pumps shall incorporate all the standard integral motor and pump protection, such as water ingress, temperature of windings and bearings, vibration, etc.
- 5.3.8 All protection devices shall operate in a fail safe manner via electrically maintained relays which de-energise on a fault condition. On sensing a trip condition, the devices and relays shall electrically lock-out the emergency stop circuit, and shall be reset manually using a front of panel common fault reset pushbutton. In addition, they shall automatically reset on control supply switch on and upon power restoration in the event of a power loss.
- 5.3.9 Electronic motor protection relays and digital overload and underload devices which provide operator interfaces shall have front of panel mounted displays and controls.

5.4 Test circuits

- 5.4.1 The motor starter control circuit supply shall be provided with a functional test facility, whereby the functionality of the control circuit and its equipment and components can be fully demonstrated with the compartment door(s) open, but whilst the motor circuit supply remains isolated at the functional unit isolating device.
- 5.4.2 A control selector switch shall be provided for 'Normal/Test' selection inside the relevant compartment
- 5.4.3 The test supplies shall be arranged to be de-energised when the motor circuit supplies are energised. The test supply shall be provided with short circuit protection, and shall be capable of isolation.

6. BUSBAR AND BUSBAR TRUNKING

- 6.1.1 The main distribution circuit through the Assembly shall comprise a main and distribution busbar system, comprising of 3 phase and neutral busbar system. The rated current of the busbar system shall match the rating of the main incomer
- 6.1.2 All main and distribution busbars, risers and droppers shall be air-insulated and shall be fabricated from hard drawn, high-conductivity copper. Aluminium busbars will not be permitted. Busbars shall be tinned for waste water treatment works (WWTW) applications. If pre-tinned copper work is provided, cut surfaces may remain bare, providing the current path is unaffected and suitable contact lubricants are used before tightening joints.
- 6.1.3 Main busbars shall be enclosed together within the top of the Assembly. No other conductors shall be run in the busbar compartment. Access to the busbars shall be through covers, requiring the use of a tool for removal. All internal fixings shall be held captive. No components shall be placed in a busbar compartment.
- 6.1.4 Main and distribution busbars shall be continuous over each section, extending to over the full length of the Assembly with the same current rating and cross-sectional area throughout their length.
- 6.1.5 Main busbars, distribution busbars and all flexible connections, shall be adequately sized, braced and supported to withstand any electromagnetic forces and thermal effects to which they may be subjected, including the occurrence of fault currents, up to the full fault levels specified.
- 6.1.6 The vertical riser buses shall be copper full height and rated for the section total load. Small openings in the vertical barriers shall permit the plug-on control unit contacts to pass through and engage with the vertical bus bars. Unused plug-on openings in the vertical barriers shall be equipped with plastic snap-in closing plugs.
- 6.1.7 All busbar connections shall use joints secured against loosening. Joints and Tee-off connections in busbars shall be made by means of high-tensile bolts, nuts and approved locking washers. A minimum of two such bolts shall be used per joint or tee. The joints shall not be taped in order to facilitate visual inspection and checking of bolt tensions. The joint contact areas shall be smooth, very flat and polished or tinned for dry jointing.
- 6.1.8 Busbars shall be provided with phase colour markers, red, white, blue (and black in the case of four wire systems). Such colour identification may take the form of coloured bands at intervals along the busbar run of not more than 800 mm. The combined width of the colour bands per phase shall not be less than 300 mm per 800 mm busbar length. The use of the convention, Red, Rear, Right shall be employed
- 6.1.9 The maximum length of any cable connections from a busbar shall be 1000 mm.
- 6.1.10 A cabled 'busbar' system of the specified radial or closed ring arrangement may be offered as an alternative to a conventional system if:
 - a) The Assembly has a rated short-time withstand current or rated conditional short-circuit current not exceeding 10 kA; or
 - b) The Assembly is protected by current limiting devices having a cut-off current not exceeding 17 kA at their rated breaking capacity.
- 6.1.11 This will generally mean that the rated current of such an Assembly will be less than or equal to 100 A.

7. INTERNAL WIRING AND FIELD CONNECTIONS

7.1 General

- 7.1.1 All wiring within the Assembly shall run directly between terminals, without any joints or other connections. Wiring shall be carried out using multistrand, single-core PVC-insulated copper conductor, 660/1 000 V grade (minimum), to SANS 1507, sized and derated where required for the currents to be carried. Single-strand conductor shall not be used and no conductor shall be less than 1,5 mm² cross-sectional areas.
- 7.1.2 Field wiring connections will be identified by others using the field device tag references. This information will be provided by the Engineer, and the Contractor shall use these field identifiers when identifying the compartment field terminations.
- 7.1.3 Wiring layout shall permit alterations to individual circuits without requiring shut down of the complete Assembly.

7.2 Cable Ways inside Assembly

- 7.2.1 All bus wiring and interconnections between compartments within the Assembly shall be contained within the enclosure, and shall be segregated in wire-ways separate from other compartments. Where such wiring is terminated in a compartment, it shall be segregated from all other wiring in that compartment. All wiring and cabling entering or leaving a compartment or passing through a partition shall do so via a permanently fixed bush.
- 7.2.2 Wiring between components shall be:
- a) carried out in a neat and systematic manner
 - b) contained in non-metallic trunking
 - c) Run to compartment doors in spiral wrapping.
- 7.2.3 Any wire containment system shall securely locate the wiring, and provide 25 % spare capacity on completion. Cableways shall have furthermore sufficient space to enable the installation and removal of any cable without the need to remove any other cable or component. Cableways shall incorporate adequate facilities to locate and support the cables.
- 7.2.4 Wiring on compartment doors shall be similarly supported, and shall be provided with support and protection across the door to compartment side wall transition, whilst permitting the door to be fully opened without straining the wiring. Wiring system accessories shall not deteriorate with heat or propagate flame.
- 7.2.5 Wiring shall be segregated according to need; circuits that enter the compartment without isolation shall be separately segregated and loomed with spiral wrapping and identified. Control circuits shall be wired in twisted pairs or screened cables, and together with data network cabling, shall be physically segregated from power circuits by barriers. If lightning and/or surge protection measures have been used to protect individual circuits, these circuits shall be segregated from the wiring of other unprotected circuits.
- 7.2.6 Cable-ways or chambers shall not contain any equipment or components.
- 7.2.7 Where field cables are terminated other than in the base of the enclosure, cable-ways or cable chambers shall be provided to transport the cables through the enclosure to the compartment or cable box at which they are glanded or terminated. Careful thought should be given to the termination of power cables and their location within the assembly.

7.3 Gland Plates

- 7.3.1 All field cables and wiring shall enter the enclosure through gland plates, which shall be located so as to facilitate the spreading of cable cores.
- 7.3.2 Gland plates shall be rigidly supported and maintain the IP rating of the enclosure
- 7.3.3 Gland plates and cable boxes shall minimise the effects of eddy currents and be suitable for the type of cable used. Single core cable gland plates shall be made of non-magnetising material.
- 7.3.4 Gland plates for bottom access cabling shall be located at least 300 mm above the finished floor level.
- 7.3.5 Each compartment gland plate shall be an integral part of the construction of that compartment

7.4 Identification

- 7.4.1 All wires shall be identified at both ends using colour coded alpha-numeric ferrules. Within a compartment, a wire shall have the same identifier at both ends; and this identifier shall not be duplicated within a functional unit.
- 7.4.2 Components and wiring shall be installed such that the identification of every wire is clearly visible and readily accessible on completion of the Assembly installation at site. Horizontal wiring identifiers shall be read left to right, and vertical wiring identifiers shall be read bottom to top.
- 7.4.3 All conductors shall be identified in conformity with the approved circuit and connection diagrams. No number shall be used more than once in each panel except where electrically identical. Wires/conductors shall have the same number on either end of the wire and all wires which are electrically identical shall have the same wire number
- 7.4.4 Circuit wiring shall be coloured in accordance with the following:


Table 6: Colour code for wiring

Wire colour	Function
Red (white, blue)	Red (white, blue) phase connections in current and voltage-transformer circuits or connections in red (white, blue) phase power circuits
Black	Neutral (star-point) connections whether earthed or unearthed insulated wires
Red / black	Connections in AC control circuits (black = neutral)
Red / black	Connections in DC control circuits (black = negative)
Green and yellow	Earth wires and earthing

- 7.4.5 Power-circuit conductors shall be coloured according to the phase to which they are connected.

7.5 Termination

- 7.5.1 Wiring shall be terminated using crimped cable ends, lugs or any other approved method that is appropriate for the conductor size and type of termination. All of the strands forming the conductor shall be connected at the point of termination. Soldered connections shall only be used on electronic equipment where it is not practicable to use any other termination method.

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- 7.5.2 Wiring with a cross section area of less than or equal to 6 mm^2 shall be terminated in terminals mounted on DIN rail. Wiring with a cross section area of greater than 6 mm^2 shall be terminated in bolted terminals.
- 7.5.3 All wiring entering or leaving a compartment shall do so via terminal rails, with the exception of specialised signal or data circuits, which may be cabled directly to dedicated connections on electronic equipment located at the periphery of the component mounting plate.
- 7.5.4 The conductor shall be clamped in such a manner that the captive clamping screw does not come into contact with the conductor. Alternatively, screw-less spring clamp tensioning terminals may be used to terminate single conductors of up to 10 mm^2 . Conductors of cross-section above 16 mm^2 shall be terminated using stud type terminals; similarly mounted and grouped on DIN rail.
- 7.5.5 No more than two conductors shall be connected to one side of a terminal. Where it is necessary to connect adjacent terminals together, proprietary shorting bars or combs shall be used.
- 7.5.6 Spare cores shall be terminated at both ends or tied back, but shall not be cut short.
- 7.5.7 All terminals shall be protected to IP2X, including stud type terminals; which shall be shrouded to achieve this. Terminals shall be segregated according to function and operating voltage; by grouping or by terminal rail mounted partitions or barriers. All stud type terminals shall be provided with individual segregating barriers.
- 7.5.8 All circuit terminal rails shall include 10 % spare space.
- 7.5.9 Terminals shall be grouped together and segregated according to operating voltage and function by terminal rail mounted barriers. Stud type terminals shall be provided with individual segregating barriers.
- 7.5.10 Terminals shall face the compartment door for ease of connection.
- 7.5.11 Terminals shall be located and spaced so as to enable the easy disconnection and reconnection of conductors, whilst providing sufficient space for the looming and spreading of cable cores. Where practicable, the layout of terminal rails shall be such that cores from the same field cable are not split between non-adjacent groups of terminals.
- 7.5.12 All wiring of external connections shall be brought out to individual terminals on a readily accessible terminal block.
- 7.5.13 All spare contacts are to be wired back to terminals.


8. LOW VOLTAGE EARTHING

8.1 Main incoming earth terminal

- 8.1.1 The Assembly shall incorporate facilities for connecting to the main incoming earth terminal, subject to its location being clearly identified and easily and safely accessible with the Assembly energised. The Assembly earthing system may comprise either an earth bar extending the full length of the Assembly or, for Assemblies with less than or equal to two (2) functional units and a supply rating of less than 100 A, a stud arrangement.
- 8.1.2 Earth bars shall:
- a) be manufactured from high conductivity copper (tinned for WWTW applications);
 - c) be located in a safe and easily accessible position;
 - d) have a minimum number of joints;
 - e) have at least one disconnecting link;
 - f) have facilities for connection to the main incoming earth terminal (the Supply Company earthing system and / or from a local earth electrode system) at each end of the bar, and
 - g) be rated and tested at a minimum of 60 % of the busbar fault withstand capacity
 - h) have a cross-sectional area of not be less than 500 mm², nor less than 50 mm in width.
 - i) be securely connected in each panel or cubicle to bare metal
- 8.1.3 Provision shall be made for the connection for the following connections to the fixed portion of the earth bar:
- a) electrical installation main bonding conductors
 - j) functional earthing conductors external to the Assembly
 - k) equipotential bonding conductors external to the Assembly
 - l) other equipment protective conductors external to the Assembly
 - m) the Assembly main earth bar / circuit, which shall be terminated onto the fixed portion
 - n) an additional 2 No. spare terminations
- 8.1.4 All metallic non-current carrying parts of the Assembly shall be bonded together and connected to the Assembly earth busbar.

8.2 Compartment earthing

- 8.2.1 Each compartment shall include an earth stud connected to the main earth bar or stud by separate connections or by a common vertical earth tape. Earth conductors to each compartment shall be sized to withstand the fault level, subject to a minimum cross-sectional area of 6 mm².
- 8.2.2 The following shall be directly connected to the compartment earthing terminal by earthing conductors with a minimum cross sectional of 4 mm² or braided straps of similar rating:
- a) compartment door
 - b) any removable cover
 - c) component / equipment mounting rails and earth terminals
- 8.2.3 A compartment may contain subsidiary earth terminals or bars to which the following circuits may be specifically connected:

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- a) 'clean' earths from instrumentation circuits and equipment
 - b) functional earths; e.g. from telecommunications equipment
 - c) surge protection earths; e.g. direct connections from lightning protection units

8.2.4 These earth terminals or bars shall be separately connected directly back to the Assembly main earth bar with 6 mm² minimum cross-section conductor.

8.2.5 Cable gland plates associated with a compartment shall be provided with an earth stud, which shall be connected directly to either the compartment earthing terminal, or to the main earth bar, with a conductor of 6 mm² minimum cross-sectional area.

8.2.6 Doors having components mounted on them shall be bonded to the main structure by means of flexible copper earth connection arranged so that it cannot be trapped as the door is opened or closed. Metal hinges shall not be considered sufficient to ensure electrical continuity.

8.2.7 Where cables carry low level high frequency signals, or are installed where there is a significant risk of high frequency interference; (e.g. in signal circuits connected to equipment containing power electronics), they shall where necessary have their screens / braids capacitively connected to earth in a proprietary manner, and proprietary means shall be included to provide 360° earthing for field cable braids / screens.

8.3 Intrinsically safe circuit earthing

8.3.1 If specified on the Project Specification, separate earth bars or studs shall be provided for connecting equipment requiring a clean earth or an intrinsically safe earth directly to the main incoming earth terminal. If required, such earth bars or studs shall be located adjacent to the equipment requiring a clean earth or an intrinsically safe earth, as appropriate.

8.3.2 Where zener diode safety barriers are contained within a compartment, they shall be separately and directly connected to the main earth bar via duplicate earthing conductors; each of 6 mm² minimum cross-section. These conductors shall be clearly identified as intrinsically safe earths.

9. POWER FACTOR CORRECTION

9.1 General requirements

- 9.1.1 Power factor correction capacitors shall be so selected and sized as to raise the lagging power factor due to induction motor loads; either individually or when summated across the Assembly, to a final corrected power factor of 0.97 lagging. When designing the system, the un-corrected power factor for each motor shall be taken as that quoted in manufacturers' literature for a high efficiency motor of equivalent rating operating continuously at its 75% duty point.
- 9.1.2 Capacitors shall be of the non-toxic self-healing dry metallised film type. Every capacitor or group of capacitors shall be provided with integral discharge resistors to reduce the residual terminal voltage to less than 50V within one minute of being disconnected from the supply.
- 9.1.3 Capacitors shall be suitable for continuous connection to a three phase low voltage industrial power supply. If the low voltage power system to which the Assembly will be connected has significant voltage waveform distortion or harmonic content, or has other capacitive or inductive networks (e.g. harmonic filters) connected to it, additional information must be obtained by the Contractor via site surveys.

9.2 Power factor correction for individual drives

- 9.2.1 Where power electronic soft starters are used, the sequence of the connection and de-energising of the capacitors shall be in accordance with the manufacturer's recommendations. Power factor correction shall not be applied to variable speed drive systems.

9.3 Bulk power factor correction

- 9.3.1 Where detailed in the Project Specification, bulk power factor correction shall be provided for the whole Assembly, in a purpose designed functional unit occupying one or more compartments within the enclosure.
- 9.3.2 Capacitors shall be arranged into banks, suitably sized to enable the incremental control of the power factor against a changing load. Each bank shall be automatically contactor controlled, in a manner that minimises switching surges, and capacitor bank status information shall be derived from the contactor auxiliary contacts. A proprietary multi-stage power factor controller, with a minimum of six steps, shall be used to monitor and sequence the switching of the capacitor banks.
- 9.3.3 Where there is provision to supply the Assembly from a generator, automatic means shall be included that will inhibit bulk power factor correction when the generator is in use.


10. POWER ELECTRONIC EQUIPMENT

10.1 Soft starting equipment

- 10.1.1 Soft starters shall comprise a proprietary item of chassis mounted equipment, designed for installation within an Assembly. They shall be rated to continuously carry the intended motor full load current, and provide the required number of starts per hour.
- 10.1.2 The soft starter shall be thermally designed to carry the motor current until the motor protection operates, and where this cannot be guaranteed, high speed semiconductor fuses shall be provided to protect the power electronics. Where such fuses are used, a spare set shall be provided and fixed within the compartment.
- 10.1.3 Soft starters shall be of a digital energy optimising design and shall incorporate appropriate motor protection, and where pumping circuits are being controlled, soft stop features shall be included. When the soft starter has completed the ramped application of motor voltage, a 'top of ramp' signal shall be generated.
- 10.1.4 Soft starters shall incorporate a built-in by-pass contactor rated for the full load running current of the motor, such that on receipt of the 'top of ramp' signal, the by-pass contactor shall close and divert the motor current away from the power electronics. When running in the by-passed condition, the motor shall continue to be provided with the full protection and monitoring features afforded by the motor starter. When a controlled stop command is received, the by-pass contactor shall be de-energised, in such a manner that the control of the motor is transferred to the power electronics.
- 10.1.5 Facilities shall be provided for the emergency stopping of the controlled motor in the shortest possible time. The emergency stop facility shall not be dependent on any software functions within the soft starter or its associated equipment and shall disconnect the soft starter from the supply by means of a full load rated line contactor fitted between the compartment isolation / protective device and the soft starter.
- 10.1.6 Where specified in the Project Specification, connectivity between the soft starter functional unit and other equipment or systems within the Assembly shall be via an open field device network compatible with the proposed PLC control system. It shall preferably use an interface device integrated within the soft starter, so as to provide remote network access to the full range of the soft starter's control and monitoring facilities.

10.2 Variable speed drives (VSDs): General

- 10.2.1 The VSD motor starter shall comprise a variable frequency converter (VFC) , phase shift transformer(s) (where required), and all other components necessary to provide the full speed and torque control of an a.c. cage induction motor over the specified operating speed range up to the motor's rated speed and full load current.
- 10.2.2 VFCs shall either be wall-mounted, housed within a motor control centre or free-standing units within their own enclosures as specified in the Project Specification.
- 10.2.3 Unless otherwise specified in the Project Specification, VFCs shall have uncontrolled rectifiers (i.e. diode front-end) with the specified pulse number (6/12/18). Either a.c. line reactors or d.c. link chokes shall be provided with all 6-pulse VFCs to reduce input current harmonics.
- 10.2.4 Where a phase shift transformer is required to achieve the specified rectifier pulse number, the transformer shall be provided as an integral component of the VSD and, unless otherwise specified in the Project Specification, shall be of the dry type and housed in a dedicated section of the VFC enclosure.

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- 10.2.5 VFCs shall be capable of operating under the service conditions specified in Clause 4 of SANS 61800 Part2, and any unusual environmental service conditions specified in the Project Specification. Functional features and performance requirements shall be in accordance with Clauses 3 and 6 of SANS 61800 Part 2 respectively as varied
 - 10.2.6 The output rating of the VFCs shall be selected to suit the associated motor and shall take into account the operating speed range.
 - 10.2.7 Every VSD motor starter shall be provided with incoming supply isolation and short circuit protection as well as an input contactor if specified in the Project Specification.
 - 10.2.8 The VSD shall provide the specified motor protection either as an integral part of the VFC or by way of a separate motor protection relay.
 - 10.2.9 Where any semiconductor or special d.c. circuit fuses are used in the VFC power circuit, a spare set shall be provided . A list of all fuses, type, ordering code and supplier and supplier details shall also accompany the spare fuses.
 - 10.2.10 The VSD control system shall incorporate comprehensive diagnostics to provide fault supervision and status indication in accordance with Clauses 3.2 and 3.3 respectively of SANS 61800 Part 2 and any additional requirements specified in the Project Specification.
 - 10.2.11 Input/output devices and communication links shall be provided as specified in the Project Specification.
 - 10.2.12 The Contractor shall ensure that the suppliers of the VFC and the associated motors confirm that their standard equipment is fully compatible and, if not, that the necessary equipment design changes (e.g. enhanced motor insulation) and/or supplementary equipment (output filters or reactors) is provided to ensure compatibility.
 - 10.2.13 The Assembly shall permit adequate heat rejection from the VSD compartments and the Contractor shall provide estimates of the total heat rejection from the Assembly. The location of the Assembly and VSD panels, and the ventilation arrangement, shall be as specified in the Project Specification.

10.3 Variable Speed Drives (VSDs): EMC Requirements

- 10.3.1 All VSDS shall comply with the requirements of product standard SANS 61800-3 for Category C2/C3 as appropriate and an EMC filter shall be provided as part of a VFC if necessary to achieve the required electromagnetic compatibility.
- 10.3.2 The supply voltage distortion limits specified in the Project Specification shall be achieved through the use of diode front-end VFCs with higher pulse numbers, active front-end VFCs or harmonic filters. Documentary proof shall be provided with the Tender that the VFC input current harmonics will be limited to the required levels.
- 10.3.3 When specified in the Project Specification, the Contractor shall carry out a harmonic survey at the point of supply to measure background voltage harmonics. The Contractor shall repeat the survey after the commissioning of all VSDs to demonstrate that the actual harmonic performance of the VSDs under worst case operating conditions does not exceed the specified limits.
- 10.3.4 Any VFC input harmonic filters or line reactors and any output filters (i.e. dU/dT, common mode or sine filters) or reactors shall be provided as part of the VFC and shall be included in the supply price. Output filters shall be provided where required to ensure motor insulation compatibility and/or control of bearing currents. Output reactors shall be provided if motor supply cables exceed the allowable length.
- 10.3.5 The design of dedicated VFC input harmonic filters shall take account of the supply impedance provided in the Project Specification, any background voltage harmonics, any

other reactances (e.g. transformers) or capacitors (e.g. power factor correction), or other filters connected to the power system, so as to avoid possible resonance problems.

10.4 Variable Speed Drives (VSDs): Control

- 10.4.1 The VSD control panel / operator interface shall be mounted in the face of the VSD panel/ Assembly. Control parameter adjustment shall be easily achievable by menu-driven option selections, with engineering options protected from unauthorised changes by the use of multi-level password protection.
- 10.4.2 All operator controls and indications shall be available front of panel, either via an operator interface / keypad, or by using discrete push-buttons and lamps, etc.
- 10.4.3 The VFC shall incorporate on-board protection, control and monitoring features, which shall include, as a minimum, the following:
- a) On
 - b) Unit Ready
 - c) Overload
 - d) Failure
 - e) Current limit
 - f) Over voltage
 - g) Manual start and stop
 - h) Raise and lower speed
 - i) Current operating status
 - j) Speed indication
- The VSD shall be such that when set in the 'manual' mode, operation from the control panel / operator interface shall be as follows:
- a) a start command shall cause a normal ramped start up to the pre-set speed
 - b) a stop command shall cause a normal ramped down stop and shutdown of the drive
- 10.4.4 All diagnostic and fault messages shall be stored, whether reset or not and it shall be possible to recall them from the operator interface/control panel.
- 10.4.5 All VFC function parameters shall be programmable from a dedicated keypad, or via a standard programming software package installed on a standard portable notebook. A serial communications port to RS232 / RS485 standard or other network communication port shall be provided for dedicated communication with the VFC, and via which all programmable, control, monitoring and diagnostic functions available locally at the VFC shall be accessible.
- 10.4.6 A copy of the configuration /standard programming software shall be provided with each VSD.

11. CONTROL CIRCUIT SUPPLIES

11.1 Provision of control circuit supplies

- 11.1.1 Fixed pattern functional units shall incorporate individual control circuit supplies that are derived from within the functional unit.
- 11.1.2 Control circuit supplies shall be 230V AC (single pole and neutral) or 24V DC as specified in the Project Specification. They shall be separately derived from double wound transformers, which where practicable shall have 400V primary windings. Double pole primary winding protection shall be provided by fuses or a miniature circuit breaker.
- 11.1.3 The rating of each control transformer shall exceed the sum of the foreseeable maximum continuous load (which for an electromagnetic device shall be the 'hold-in' VA) plus the in-rush current of the largest or simultaneously operating load device(s) (e.g. the 'pull-in' VA).
- 11.1.4 Control circuit supplies shall comply with SANS 60204-1, and the neutral terminal of each transformer secondary winding shall be provided with a removable link, and shall be connected to earth. Secondary winding overcurrent protection shall be provided.

11.2 Control circuit features

- 11.2.1 One pole of every contactor and auxiliary relay coil, timer, etc. shall be connected directly to the neutral (i.e. earthed) side of the control supply. Each control circuit shall be sectionalised and arranged such that where practicable, discrimination is achieved under fault conditions.
- 11.2.2 Where possible, common controls and ICA compartment circuits shall operate at 24V DC, and shall interface with the functional unit 230V AC control circuits by means of 24V DC interposing relay(s) located in the functional units.

12. SIGNS AND LABELS

12.1 General

- 12.1.1 Safety signs and labels shall be provided wherever necessary in relevant languages so as to unambiguously communicate safety and functional guidance to any person who may operate the Assembly or otherwise come into contact with any part of the electrical system forming a part of the Assembly, and shall be provided for the specific identification of every component contained within the Assembly.
- 12.1.2 Signs and labels shall be located in such a manner that:
- it is obvious as to the nature and location of the hazards or component(s) to which they relate
 - when mounted on any enclosure cover or plate, there is no possibility of that cover or plate being interchanged with any similar item on that Assembly or on any other Assembly supplied to the same site
 - they are not fixed to easily removable parts (e.g. trunking covers, etc.), unless their purpose is to warn of the consequences of removing a removable part
 - they are at all times adjacent to the item to which they refer, and accommodate situations where components could be moved along a DIN mounting rail
 - they will not be obscured by any equipment, components, or wiring, etc.
 - they are legible and will remain easily read throughout the life of the Assembly
 - Signs and labels shall be securely and permanently fixed using an appropriate number of corrosion resistant, mechanical fixings. The fixing of labels, safety signs and notices shall not affect the IP rating of the Assembly.
- 12.1.3 Short individually fixed labels covering several items only, shall be used in lieu of long multi-legend labels; e.g. above a row of indicator lamps.
- 12.1.4 Self-adhesive, vinyl safety signs may be used if there is no requirement for special legend and propriety safety signs are available.
- 12.1.5 Safety signs and labels shall be of such size that the legend thereon is clearly legible from the operating position (or a 3m distance), and the pictograph and its accompanying text shall be chosen so as to provide the appropriate communication in an explicit and unambiguous manner.
- 12.1.6 Safety signs and labels fixed to the outside of the enclosure shall be manufactured from 1.5mm thick anti-reflective polycarbonate with the legend reverse screen printed, or alternatively from 3mm thick bevel-edged clear perspex rear engraved with black characters. Internal labels may be manufactured from a laminated plastic material which shall normally provide a black legend against a white background. Where specifically agreed with the Engineer, internally mounted labels and charts, e.g. for distribution boards, etc., may be of permanently printed plastic, plastic laminated thin card, or thin card protected behind perspex.

12.2 Safety Signs

- 12.2.1 As a minimum, safety signs shall be fitted to removable covers over busbars and live connections, and to doors of compartments containing:
- incoming supply cable termination points
 - internal switching and isolation devices

- c) incoming or internal means of isolation; stating the highest voltage controlled by the means of isolation
- d) functional units incorporating capacitors
- e) more than one supply or multiple control circuits originating elsewhere
- f) equipment located in a 'safe area' but associated with certified apparatus located in a hazardous area; a sign shall also be fitted at the safe area cable termination rail.

12.2.2 A safety sign identifying the operating voltage shall be placed in any compartment where there is equipment, components, or wiring, that can be energised at above extra low voltage.

12.2.3 Where there is no suitable standard symbol or pictograph, an application specific sign may be produced using simple and appropriate symbols, pictographs, and text, to indicate the hazard in a simple and straight forward manner that is acceptable to the Engineer.

12.2.4 Multipurpose signs shall be used where there is a need to communicate multiple hazard messages.

12.3 Labelling

12.3.1 The text of every label, excluding individual internal component identification labels, shall be as agreed with the Engineer.

12.3.2 Every Assembly shall be provided with a name plate detailing the following:

- a) Manufacturer's name or trademark
- b) Manufacturer's contact details
- c) Manufacturer's type designation, serial / identification number
- d) Date of manufacture
- e) Rated operational voltages, frequencies, and number of phases
- f) Continuous busbar rating
- g) Short circuit withstand current and duration
- h) IP rating

12.3.3 An application name shall be prominently displayed on the Assembly, as detailed in the Particular Specification.


12.3.4 Each compartment shall be identified with a designation label which shall include the full plant functional name and the alpha numeric reference cross referenced to as-built drawings and documentation contained in the Operation and Maintenance Manual. For rear access Assemblies, a duplicate designation label, mounted adjacent to the gland box, shall also be provided at the rear of each compartment.

12.3.5 The material used shall be selected having regard to the size and fixing methods of the label and the label shall not warp in service. Labels mounted on the outside of the Assembly shall rectangle in form and be manufactured of either:

- a) Laminated plastic, engraved so as to produce black letters on a white background
- b) Engraved sandwich board ("Trifoliate", "Darvic" or equal)
- c) Reverse engraved acrylic material ("Perspex") with filled letters and reverse sprayed

12.3.6 For outdoor applications (where specified) labels shall be brass or aluminium (with letters filled in black), lightly sanded with fine grit paper and clear lacquered

12.3.7 Labels for door mounted components and labels used inside the Assembly shall be to the same standard or may alternatively be printed using an approved, propriety system.



12.3.8 Text characters shall be uniform in height, in upper case (except where standard abbreviations of units are used, e.g. kWh, kVA, etc.) and of the following minimum dimensions:

- a) application labels: 8mm
- b) compartment designation labels: 6mm
- c) information or warning labels: 6mm
- d) component identification labels: 3mm

12.3.9 All components shall be clearly labelled. Internal components shall be clearly identified by individual labels to indicate the equipment to which they relate. The component identification labels shall correlate with the Assembly drawings and documentation. If this is not practical due to space restrictions, common labels (e.g. diagrams may be used).

12.3.10 Current transformers shall be provided with separate and individual identification and rating plates.

12.3.11 Each distribution board shall be provided with a circuit chart laid out in a way that matches the orientation and layout of the protective devices in the distribution board.

12.3.12 A typed circuit chart shall be permanently fixed inside each Assembly or immediately adjacent to the distribution board. The chart shall be laid out in accordance with the physical arrangement of the protective devices that it is easy to relate the circuit chart details to the appropriate protective device. As a minimum, the chart shall be enclosed in a transparent protective cover attached to the inside of the compartment door.



13. INSTALLATION REQUIREMENTS

13.1 Shipping

- 13.1.1 Assemblies shall be shipped in sections to facilitate field handling for transportation and installation. The shipped sections shall be joined together to form a complete unit assembly.
- 13.1.2 Preparation for shipment shall protect the Assembly auxiliary devices accessories, etc. against corrosion, breakage or vibration injury during transportation and handling.
- 13.1.3 Disassembly shall be into the largest components or sub-assemblies possible, consistent with packing, road transport and handling limitations.
- 13.1.4 All parts shall be clearly and lastingly match marked to facilitate field erection prior to disassembly and packing for transport. Instructions shall be provided for reassembly of sections in the field or accompanied by a qualified representative from the Assembly Manufacturer.
- 13.1.5 The Contractor shall be responsible for delivery including loading and unloading of all equipment to site.
- 13.1.6 The Contractor shall provide information (in time) regarding specialised handling and storage requirements/techniques for equipment on the site until finally installed in the operating location.

14. LOCAL CONTROL PANELS

14.1 General requirements

- 14.1.1 The START/STOP pushbutton or control station shall be mounted adjacent to the drive.
- 14.1.2 The enclosure incorporating the pushbuttons, selector switches and indicating lights shall be fully water, weather and vermin-proof and shall have a minimum rating of IP65. The enclosure shall be manufactured from 3CR12 and shall be painted B26 to SANS 1091.
- 14.1.3 All pushbutton control station shall be pedestal mounted on a bracket at least 1 000 mm above ground/floor level.
- 14.1.4 All START pushbuttons shall be green and the operator shall be flush with the surrounding bezel.
- 14.1.5 All STOP pushbuttons shall be a red mushroom head latching push button and shall serve as an emergency stop.
- 14.1.6 All selector switches shall be rotary selector switches with black operators.
- 14.1.7 The control/pushbutton station shall be adequately designed to provide space for the following:
 - a) The required pushbuttons, selector switches and indicating lights complete with their appropriate labels.
 - b) Termination of all control wiring associated with the drive or group of drives. The minimum terminal strip length is 150 mm. A single multicore control cable shall be installed from the Assembly to the station, from where the required signals will be individually wired.
 - c) Stations for submersible equipment shall in addition of the required control cables, also provide for the termination of all the required power cables.
 - d) Sufficient space shall be provided for the glanding of the required cables.
- 14.1.8 All further requirements pertaining to the design, construction, installation and commissioning of control panels (e.g. Labelling, earthing, commissioning, etc.) shall be as specified in the relevant subsections of this Specification.

14.2 Start/Stop pushbutton stations

- 14.2.1 In addition to the above general requirements, START/STOP pushbutton station shall confirm to the following additional requirement:
 - a) One START pushbutton
 - b) One STOP pushbutton., The STOP pushbutton shall be twist to release.
 - c) Where reverse local control is required the reverse button shall not latch unless required.

15. FUNCTIONAL DESIGN

15.1 Specification to the Contractor

The Engineer shall provide the Contractor with the following information, which will form the basis for the design of the Assembly:

15.1.1 The Particular Specification

The Project Specification will detail all project specific requirements.

15.1.2 MCC and Local Control Table

The MCC and Local Control Table will be a schedule of all external connections and their function, ratings, etc. It gives an indication of each load's kW rating and the relevant circuit breaker size that must be selected. Also stated will be the type of starting, the local visual indication and the requirements for manual, automatic and local control needed.

15.1.3 I/O Schedule

The I/O Schedule will detail all the input and output signals (analogue and digital) for the controller connections, and the relevant equipment part it connects to.

15.1.4 Technical Data Sheets

The Technical Data Sheets are intended for use as standard templates, which will be completed and inserted into the Project Specification documents, so as to detail the project and product specific requirements for each Assembly as a whole, and for its constituent functional units.

Project specific configuration of the Technical Data Sheets will take the form of a 'YES' 'NO', insertion of a value or , together with the provision of an associated Particular Specification clause, cross-reference, or stated requirement, etc., as appropriate. When compiling a Project Specification document, only those Technical Data Sheets applicable to the required functional units will be included.

One set of Technical Data Sheets will be prepared per Assembly, unless therein detailed otherwise. Individual Technical Data Sheets may be duplicated if applicable, in order to accommodate the extent of scheme specific information.

15.1.5 Control Philosophy

The Control Philosophy will detail the functionality of all control and automation systems

15.1.6 Cable Block Diagram

The cable block diagram is a schematic that shows how the components of the Assembly is connected to the equipment and motors that it controls. It also indicates starting method, cable and circuit breaker sizes.

15.1.7 Assembly general arrangement drawing

A proposed layout shall be provided for the Contractor as indication of the relevant size constraints for the Assembly. It shall also indicate the number of functional units (e.g. motor starters, feeders, etc.) that is required for the Assembly.

15.1.8 Building arrangement drawing

A drawing indicating the Switchgear-room layout shall be used for functional considerations of the Assembly design. This drawing could be provided under the Civil part of the project.

16. TESTING AND COMMISSIONING

16.1 General requirements for testing

- 16.1.1 On completion of manufacture, the Assembly shall be subjected to a factory acceptance test (FAT), comprising the Manufacturer's in-house tests, and the repeat tests witnessed by the Client and the Engineer.
- 16.1.2 Once the witnessed FAT has been carried out, signed off, and any remedial works have been completed and re-tested, the Assembly is ready for delivery to site. Once erected in position, the Assembly shall be subjected to a witnessed site acceptance test (SAT).
- 16.1.3 Once the SAT has been carried out and signed off, any remedial works shall be completed and re-tested. Plant installation and site cabling will then be carried out by others, and on its completion, witnessed commissioning shall commence.
- 16.1.4 The manufacturer shall allow for each test (apart from in-house tests) to be witnessed by both the Client and the Engineers simultaneously. An individual testing activity shall not be considered to have been completed until any results have been recorded, and it has been signed off by the Engineer.
- 16.1.5 The manufacturer shall provide the Client and Engineers with all reasonable facilities, including testing staff and test equipment, to carry out the inspections and tests, and to check the Assembly for compliance with all of the Client's requirements.
- 16.1.6 The manufacturer shall ensure that all testing is carried out in a safe manner, and shall protect those witnessing from danger; in accordance with the Occupational Health and Safety Act.
- 16.1.7 In order to demonstrate the functionality of each circuit, external devices shall be simulated in a representative manner. A small motor shall be used as a test load where motor starters incorporate power electronics. During development, software may be electronically verified away from the Assembly using a simulation / diagnostic package; notwithstanding this, control systems shall be witnessed tested with the software loaded into the programmable devices, and with simulation of the physical I/O devices.
- 16.1.8 Where the Assembly incorporates equipment requiring special testing facilities or procedures, the manufacturer shall ensure that appropriate resources are available; including where necessary, representatives from the equipment Manufacturer.

PROCEDURE FOR TESTING AND COMMISSIONING

Action	Action By	Documentation
<pre> graph TD DA[Design Assembly] --> C1{Check} C1 -- Revise --> DA C1 -- Approve --> M[Manufacturing] M --> IFAT[In-house FAT] IFAT --> FAT{FAT} FAT -- Revise --> IFAT FAT -- Approve --> DTS[Delivery to Site] DTS --> C2(()) C2 --> SAT{SAT} SAT -- Revise --> C2 SAT -- Approve --> OMC[O&M Manual & COC] OMC --> C3{Check} C3 -- Revise --> OMC C3 -- Approve --> FTC[Final Test & Commissioning] </pre>	<p>Manufacturer/Contractor</p> <p>Engineer</p> <p>Manufacturer/Contractor</p> <p>Manufacturer/Contractor</p> <p>Manufacturer/Contractor/ Engineer/ Client (If required)</p> <p>Manufacturer/Contractor</p> <p>Manufacturer/Contractor /Engineer</p> <p>Contractor to provide to Engineer</p> <p>Engineer</p> <p>Contractor provides O&M Manuals</p> <p>Manufacturer/Contractor /Engineer/Client(If required)</p>	<p>SLD drawings, Assembly GA drawings</p> <p>In-house FAT document</p> <p>Final FAT document, Functional Specification</p> <p>SAT document</p> <p>Draft Copy of O&M manual COC</p> <p>3 Copies of approved O&M manual</p> <p>Commissioning Test document</p>

FAT: Factory Acceptance Test; O&M Manual: Operating & Maintenance Manual; SAT: Site Acceptance Test; COC: Certificate of Compliance

16.2 Factory acceptance tests (FATs)

- 16.2.1 The manufacturer shall perform his in-house works tests in accordance with the proposed FAT procedures, and shall satisfy himself as to the accuracy and quality of the manufactured Assembly in accordance with the accepted design. Once the in-house FAT has been carried out, signed off by the manufacturer, and any remedial works have been completed and re-tested, the tests shall be repeated and witnessed by the Client (if required) and the Engineer.
- 16.2.2 The in-house and the witnessed FATs shall check compliance with SANS 60439-1, and shall include the following:
- a) A thorough external and internal visual inspection.
 - b) Confirmation of adequate earthing.
 - c) Secondary injection testing of all protective circuits shall be carried out, except where discrete current transformers are used; in which case sufficient primary injection testing shall be carried out to prove the ratio and the polarity.
 - d) Meggar tests shall be performed across all main and distribution busbar joints.
 - e) All busbars shall be subjected to a single witnessed reduced voltage dielectric 'flash' test; the in-house test shall also be at a reduced voltage.
 - f) All power circuits shall be subjected to insulation resistance tests.
 - g) The operation of every mechanical device and interlock shall be verified.
 - h) All circuits and their functionality shall be tested as detailed in the Control Philosophy and MCC and Local Control Table.
 - i) Any other test necessary to verify satisfaction with the requirements of Table 7 of SANS 60439-1.
- 16.2.3 When testing the performance of any software, it shall be demonstrated using the hardware intended to be incorporated within the Assembly, and where this is not possible appropriate operator interfaces, programming units, and terminal units, etc. shall be provided. Where it is necessary to demonstrate an interface with a piece of unavailable equipment to be supplied by others, appropriate means to replicate that equipment and simulate the interface shall be provided.
- 16.2.4 The Engineer preserves the right to cancel and postpone tests if he finds that the Contractor has not made reasonably sure that the test will be successful. Any extra costs incurred shall be borne by the Contractor.

16.3 Site acceptance test (SAT)

- 16.3.1 All equipment and every circuit that was altered or disturbed subsequent to the completion of the FAT, or for shipping and site erection, shall be specifically re-tested for integrity and functionality.
- 16.3.2 During the SAT, all busbar joints that are re-tightened on site shall be subjected to a further Meggar test, and all busbars shall be subjected to a single witnessed full voltage dielectric 'flash' test.
- 16.3.3 The process functionality of each aspect of the control system and its operator interface shall be demonstrated, including the correct operation of all I/O and network links external to the Assembly or not otherwise tested during the FAT.
- 16.3.4 A COC shall be provided to the Engineer, before final Testing and Commissioning can start.



16.4 Commissioning and other tests

- 16.4.1 The manufacturer shall provide attendance during the commissioning of the Assembly, whereby the functionality of the Assembly and its control system and software shall be proven. During commissioning the manufacturer shall make such adjustments, software modifications, and circuit changes, as are deemed necessary to provide the level of plant functionality and performance specified by the Client. All such changes shall be immediately incorporated into the 'as installed and tested' documentation and the Operating and Maintenance Manual, by the Contractor.
- 16.4.2 The manufacturer shall provide an acceptance document, to detail and record the tests and their anticipated results, and the acceptance document shall have provision for recording and signing off the results.

17. DOCUMENTATION AND TRAINING

17.1 General

17.1.1 All drawings, information, and documentation shall be in English, and each item shall be identified with:

- a) the Client's name and contact details
- b) Client's project / scheme / contract reference title and numbers
- c) the Engineer's name and contact details
- d) Engineers reference numbers
- e) Contractor's works / contract / order references.

17.1.2 Drawings for acceptance shall be provided on A4 or A3 paper copies as specified.

17.2 Drawings for Approval by the Engineer

17.2.1 The following documentation and drawings shall be submitted to the engineer prior to the procurement or manufacturing of Assemblies and related equipment:

- a) Cable block diagrams.
- b) General arrangement and elevation drawings, compartment door layouts, typical component mounting plate layouts, and foundation plans.
- c) Electrical schematic diagrams showing all equipment and components incorporated into the Assembly. Known circuitry outside of the Assembly and connected to it, shall be shown on all drawings. Drawings shall be cross-referenced using a grid / line reference system.
- d) Protective device grading for overcurrent, short circuit, and earth fault / leakage devices incorporated within the Assembly, together with a schedule of proposed settings that will ensure discrimination.
- e) PLC software and configuration documentation; including ladder logic diagrams and HMI display screens, etc. The documentation shall be complete and annotated with purpose, function, duty, cross-references, and descriptions, etc.; sufficient to guide an unfamiliar person through the operation of the software.


17.3 Testing Documentation and Reports

17.3.1 The FAT and SAT shall be according to BS EN 62381.

17.3.2 A factory acceptance test (FAT) document shall be provided to the Engineer prior to the witnessed FAT. This documentation shall show the manufacturer's in-house test procedures and results for all items of equipment, components, hardware, and software. The document shall show hardware checks, the software simulation procedures, and their combined functional testing.. It shall comprehensively and clearly show the test results of the in-house testing. The subsequent report of the FAT witnessed by the Engineer shall be appended to this documentation.

17.3.3 The Contractor shall provide his own testing report template to document the FAT witnessed by the Engineer. This shall be to the satisfaction of the Engineer.

17.3.4 A site acceptance test (SAT) document shall be produced, which shall detail all tests necessary to demonstrate the functionality of the Assembly following its final erection on site. This shall include details of tests and checks on all circuits disconnected for shipping, together with any equipment, components, wiring, or software altered or incorporated into the Assembly; following the completion of the witnessed FATs.

- 
- 17.3.5 All drawings, schedules, listings, and other design documentation for acceptance shall be supplied as a comprehensive and integrated package and collated into folders; unless otherwise agreed with the Engineer. Three copies of appropriate documentation shall be submitted on each occasion that agreement is sought.
- 17.3.6 A Certificate of Compliance (COC) shall be provided for all new Assemblies. For all refurbished Assemblies, a letter shall be provided listing all the repairs and stating that the Assemblies are still deemed to be reasonably safe.
- 17.3.7 The FAT, SAT, and COC shall each have been submitted and agreed with the Engineer, prior to the commencement of final testing and site commissioning.

17.4 Certificate of Compliance

- 17.4.1 A Certificate of Compliance (COC) shall be provided for all new Assemblies. For all refurbished Assemblies, a letter shall be provided listing all the repairs and stating that the Assemblies are still deemed to be safe.
- 17.4.2 The original COC shall go to the client's electrical representative.
- 17.4.3 A copy of the COC shall be included in the O&M Manual.

17.5 Operating and Maintenance Manual


- 17.5.1 One copy of the draft operating and maintenance manual and spare parts list shall be provided at an agreed date; in advance of the date of the start of the final testing and commissioning SATs, for acceptance by the Engineer. Three copies of the final editions shall be provided to the Engineer by an agreed date before successful completion of final testing and commissioning.
- 17.5.2 The Operating and Maintenance Manual shall be bound into a suite of hard-backed ring binders, and shall be provided with an index of all drawings pertinent to the Assembly. The index shall include each drawing's origin, number, issue, status, and the Client's drawing number (where issued by the Engineer).
- 17.5.3 The Operating and Maintenance Manual shall include the following:
- a) All design drawings and documentation relating to the Assembly; as delivered and tested.
 - b) 'As installed and tested' records showing verification against stated design and installation criteria, including a schedule of all the final settings for all user adjustable equipment and components, and copies of all documentation presented and completed during the FATs, the SATs, and any other specified tests on completion.
 - c) Schedules of plant and equipment for each compartment / circuit; including a listing of the applicable standards, manufacturer, settings, type number, re-order code, etc., for each item of equipment and component included within the Assembly.
 - d) Manufacturers' contact details, technical information sheets for all items of equipment and components included within the Assembly. Manufacturers' catalogues may be provided subject to clear identification of the relevant components. All individual manufacturers' equipment / component test certificates and certificates of conformity, shall be included.
 - e) Inspection, testing, and maintenance recommendations, including detailed and specific operation, maintenance, and diagnostic data, and safe isolation information suitable for use by maintenance personnel, shall be provided for all equipment, components, and systems incorporated into the Assembly.
 - f) Schedule of spares provided with the Assembly, including manufacturer, description, part number, order code, and quantity.

- 17.5.4 The Operating and Maintenance Manual shall include detailed descriptions for use by the Client, on how the controlled plant and its management systems are intended to operate and be operated; under both manual and automatic control. Clear and detailed descriptions for each element of the Assembly shall be provided; and shall include system objectives, controlled plant start-up and shut-down procedures, automatic control, manual intervention, primary and secondary control routines, plant selection including duty and standby options, local and remote selections, operational and safety constraints, status information, alarms and control interfaces with control systems, fault routines, etc.
- 17.5.5 The Operating and Maintenance Manual shall include 'as-installed and tested' information on both the hardware and software for each programmable device incorporated within the Assembly, including:
- a) Overview of system operation in relation to the controlled plant.
 - b) System configuration.
 - c) Manufacturers' literature on operation, maintenance and testing of hardware and ancillaries, programming instructions, and diagnostics.
 - d) Hard copy program; with listings fully documented.
 - e) Listing of the final settings of all process dependent variables.
 - f) Permanent back-up copies, licensed in the name of the Client, shall be provided for all software, including operating programmes, application programs, and configuration software for all configurable devices.
- 17.5.6 Any interconnecting leads, protocol conversion modules, connectors, etc. necessary to connect and communicate with each programmable / configurable device to a standard portable Notebook.
- 17.5.7 Manual format shall be A4 size on the filing side which shall be vertical with 20 mm margin for filing.

17.6 Training

17.6.1 General

- a) The LV switchgear and Control Gear training shall form part of the overall training programme.
- b) The Contractor shall conduct training courses for designated personnel in the maintenance and operation of the Assemblies.
- c) The Assemblies shall be in a complete working order before training shall commence.
- d) A training schedule, together with the name and background of the person who will perform the training, shall be submitted to the Engineer for approval.
- e) Training and training manuals shall be based on the O&M Manuals.
- f) Training manuals shall be delivered for each trainee with two additional copies delivered for archival at the project site. The manuals shall include an agenda, defined objectives for each course.
- g) Where the Contractor presents portions of the course material by audio-visuals, copies of those audio-visuals shall be delivered to the Employer as part of the printed training manuals.
- h) The Employer reserves the right to videotape the training sessions for later use.
- i) The training shall include operator training and technical/maintenance training.
- j) During the installation phase, a person will be designated by the Employer to be closely involved with the installation and commissioning process. The intention is not to interfere with the Contractors' installation team, but to do observation in order to obtain the



maximum possible information regarding the installation, to enable efficient maintenance to be undertaken by the Employer after final hand-over and expiring of the guarantee period.

17.6.2 Operations & Maintenance training sessions

- a) There shall be training sessions for the operation and maintenance of the Assemblies
- b) The program for the training shall include instruction for at least one day per Assembly (8 hours) instruction on-site.
- c) The program shall at a minimum cover the following:
 - i) General system overview
 - ii) Functional operation of the system i.e.:
 - System start-up and shut-down procedures
 - System access requirements
 - Alarms
 - Fault Finding
 - Backup Power Procedure (if applicable)
 - Incident Reporting
 - iii) Maintenance
 - Maintenance Schedule
 - Standard Maintenance Procedures
 - Spare Part Lists
- d) Upon completion of the course, the operators should be fully proficient in the system operation and have no unanswered questions regarding the system.



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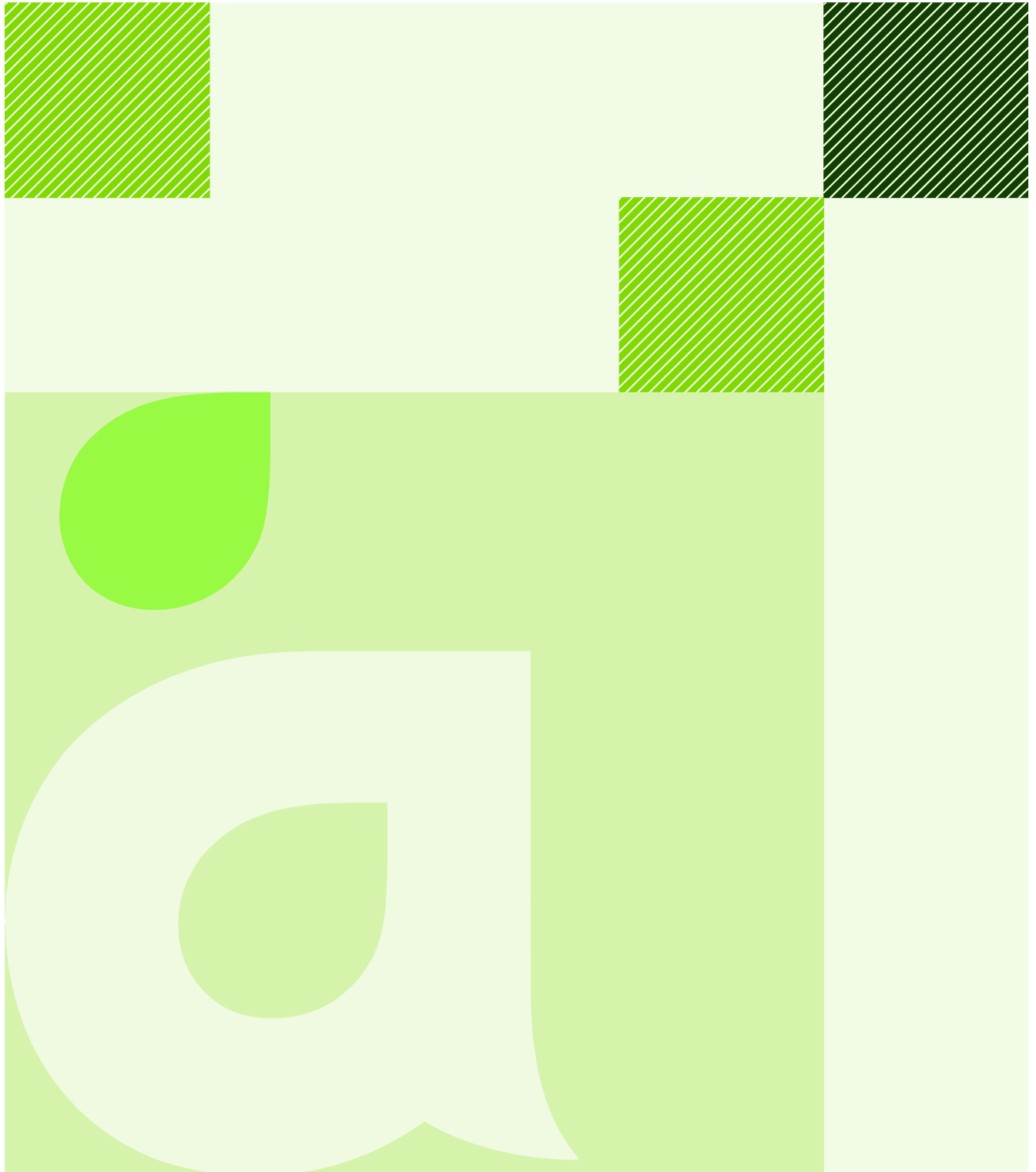
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Engineering Standard

Low Voltage Cables

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1. SCOPE

1.1 Application

- 1.1.1 This document specifies the standard requirements for the supply, delivery to site, site installation, site testing, commissioning and handover of Low Voltage cable systems.
- 1.1.2 This document specifies the standard requirements for the design, installation, testing and commissioning of electrical installations operating on voltages up to 1 000 Volts AC / 1 500 Volts DC.
- 1.1.3 The primary intention of this specification is to ensure the provision of an electrical installation, which has been designed and constructed to ensure safe, reliable, operation and to facilitate safe inspection, testing and maintenance.
- 1.1.4 Note, however, that this specification only covers such installations (or sections of installations) that are covered by SANS 10142-1. Note also that certain provisions of this specification are inappropriate for direct application to installations where additional measures (such as earthing, intrinsic safe equipment, etc.) are required by SANS 10142-1 and SANS 10108 (i.e. medical and hazardous locations). For these types of installations, SANS 1411.

1.2 Electrical System Characteristics

- 1.2.1 The design of the installation shall comply with SANS 10142-1.
- 1.2.2 The design of the installation shall consider the following supply characteristics:
 - a) Voltage, frequency and number of phases
 - b) Maximum prospective short circuit current (phase to phase and phase to neutral)
 - c) Type of system, e.g. TN-S, TN-C-S
 - d) Maximum earth loop impedance of the earth fault path external to the installation
 - e) Type and rating of the cut-out or switch device
 - f) Load capability of the supply source, particularly the effects on the supply voltage of the starting of new equipment
- 1.2.3 The installation of protective devices shall be correctly co-ordinated within the installation and with respect to existing installations. Discrimination studies shall be performed to validate the co-ordination of the installation.
- 1.2.4 All equipment which requires operation or attendance by a person, or requires cleaning or maintenance in service, shall be constructed and installed to allow adequate and safe means of access and adequate working space for such activities.
- 1.2.5 Where additions or alterations to an existing installation are to be performed, the rating and condition of existing equipment, including that associated with the supply, shall be verified to confirm its suitability to carry any additional load. The earthing and equipotential bonding arrangements shall also be verified. No addition or alteration shall have an adverse effect on the existing installation.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification identifies the Employer's standard modifications and requirements which shall be applied to the statutory and recognised standards. The detailed specification of the project or site-specific requirements will be found in the Particular Specification and its accompanying Technical Data Sheets, which shall be read in conjunction with this Specification.
- 2.1.2 Any items not specifically detailed in this Specification, which are necessary to provide a safe and fully operational working system, shall be deemed to be included.
- 2.1.3 The Contractor shall operate an auditable quality assurance procedure covering the design, construction, inspection and testing of the installation.

2.2 Regulations, Specifications and Standards

- 2.2.1 The design, construction, inspection and testing of the installation shall comply with all relevant Statutory Regulations and Directives including:

- a) Occupational Health and Safety Act (Act 85 of 1993)
- b) Construction Regulations 2003 issued in terms of Section 43 of the Act
- c) Local Fire Regulations; and
- d) Regulations of the Local Supply Authority

and the latest editions (current at the time of Tender) of all relevant South African National Standards, as well as International Standards, including but not limited to:

Table 1 Reference Standards

Standard Number	Description
SANS 1213	Mechanical cable glands
SANS 1411	Materials of insulated electric cables and flexible cords
SANS 1507	Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3 300 V)
SANS 10199	The design and installation of earth electrodes
SANS 10225	The design and construction of lighting masts
SANS 10142-1	Wiring of Premises Part 1: Low Voltage Installations
SANS 60614-2	Conduits for electrical installations - Particular specification for conduits
IEC 50086	Conduit systems for cable management

- 2.2.2 The installation shall also comply with:

- a) This Specification, including all Technical Data Sheets; and
- b) Any documentation issued by, or on behalf of, the Employer in respect of the Installation.



3. GENERAL


3.1 General

- 3.1.1 Cables shall be manufactured strictly in accordance with SANS 1507.
- 3.1.2 Cables shall be delivered within 12 months of manufacture and shall be delivered to site on cable drums or coiled with protective wrappings.
- 3.1.3 Cables shall be delivered, stored and handled in accordance with the manufacturer's instructions. Where the performance of the cable is likely to be adversely affected by the ingress of moisture, it shall be adequately sealed at both ends
- 3.1.4 The end protruding from the drum shall be protected against mechanical damage.
- 3.1.5 Cable selection and sizing should comply with SANS 10142-1. Cables and their wireways shall, where required by SANS 10400 Part T to be protected against the effects of fire, be selected and installed in accordance with the provisions of such code.
- 3.1.6 Cables shall have copper or aluminium conductors according to SANS 1411-1. Cores of cross sectional area greater than 1,5 mm² shall be stranded or flexible.
- 3.1.7 Where neutral conductors are to be provided, they shall be of the same cross sectional area as the associated phase conductor, unless otherwise specified in the Particular Specification and drawings.

4. LOW VOLTAGE CABLES

4.1 Types of Low Voltage Cables

- 4.1.1 Unless otherwise specified, all LV cables shall have copper conductors to SANS 1411-1. Cores of cross sectional area greater than $1,5 \text{ mm}^2$ shall be stranded or flexible. Where neutral conductors are to be provided, they shall be of the same cross sectional area as the associated phase conductor, unless otherwise specified in the design documentation and drawings.
- 4.1.2 All LV cables used in an electrical installation shall be as specified in the Particular Specification (or cable schedule as part of the Particular Specification) and shall comply with either of the following:
- a) PVC/AWA/PVC and PVC/SWA/PVC
 - i) Cables shall comply with SANS 1507-3 and be rated at 600/1000 V.
 - ii) Single core cables shall have aluminium wire armouring.
 - iii) Multicore cables comprising five conductors and above shall have each core individually coloured, or, where not available, be coloured white with phase identification in black numerals.
 - b) XLPE/AWA/PVC and XLPE/SWA/PVC
 - i) Cables shall comply with SANS 1507-4 and be rated at 600/1000 V.
 - ii) Single core cables shall have aluminium wire armouring.
 - c) PVC/PVC
 - i) Cables shall comply with SANS 1507-3 and be rated at 600/1000 V.
 - d) XLPE/PVC
 - i) Cables shall comply with SANS 1507-4, and be rated at 600/100 V.
 - e) Single Core PVC
 - i) Cables shall comply with SANS 1507-2 and be rated at 600/1000 V.
 - ii) The insulation shall be phase coloured, and, where used in single phase systems, line cables shall be red, neutral cables black and earth cables yellow and green.
 - f) Flat Twin and Earth PVC
 - i) Copper conductors shall comply with SANS 1411-1, PVC insulated to SANS 1411-2, laid up with a bare copper earth continuity conductor between them, with PVC bedding to SANS 1411-2.
 - ii) Cables shall be rated at 300/500 V.
 - g) Fire Resistant Cables
 - i) Cables requiring protection against the effects of fire shall be of fire-resistant construction (note here that “fire-rated” cables are not the same as “fire-resistant” cables).
 - ii) Fire-resistant cables shall thus comply with SANS 60331-21 and / or BS EN 50200.

- 
- iii) Except where prior approval in this regard has been granted by the Engineer, increasing the resistance to fire of normal (i.e. non-fire resistant) cables though the application of a coat of fire-resistant compound will not be accepted.

4.2 Cable Accessories

4.2.1 Cable Markers

Concrete markers for the indication of cable or trench routes shall be placed at a minimum of 50 m intervals, changes in trench or cable direction and at road crossings. The markers shall protrude by 25 mm above finished ground level, except where they are likely to cause obstruction, when they shall be laid flush with the finished ground level.

5. INSTALLATION OF CABLES

5.1 General

- 5.1.1 The cable installation shall comply with the requirements of SANS 10142-1.
- 5.1.2 Cables shall be installed strictly in accordance with the cable route drawings.
- 5.1.3 Cables installed in groups shall run in straight lines and not cross over each other, except where transposing of cables is required to reduce capacitive or inductive effects.
- 5.1.4 Cables installed above ground shall, as far possible, run parallel with the lines of building construction. Cables and wireways shall then only be installed in horizontal and vertical runs, and the installation shall be as visually unobtrusive as possible.
- 5.1.5 Cables buried below ground shall, as far as possible, follow features of the site such as roadways and building lines.
- 5.1.6 Where a redundant cable installation is required, the cables shall not be installed along the same route, and their routes shall be through separate fire compartments (except where no separation occurs, as may be the case in the vicinity of the source and load).
- 5.1.7 Cables and their support systems shall not be fixed to protective barriers, guards or directly to guard-rails.
- 5.1.8 Cables shall not be exposed to direct sunlight after installation. If the cable route compels the support system to be in direct sunlight, the Contractor shall ensure cables are covered with a suitable canopy or cover of the same material as the support system (tray). Cables shall be installed strictly according to the manufacturer's requirements pertaining to:
 - a) Maximum tensile or compressive stresses (e.g. due to pinching or squashing)
 - b) Minimum bending radii
 - c) Temperature of installation; and
 - d) Operating environment
- 5.1.9 No joints or repairs to outer sheathings or insulation shall be allowed in low-voltage cables without the prior approval of the Engineer.
- 5.1.10 Propriety (i.e. suited to and manufactured for such use) cable support systems shall be used.
- 5.1.11 Unarmoured cables shall only be used where there is no risk of mechanical damage.
- 5.1.12 Fire resistant cables shall only be supported by fire resistant cable support systems.
- 5.1.13 After cable installation, the open end of all cable sleeves and the openings in building structures specifically provided for the passage of cables (including unused openings) shall be fire sealed to SANS 10177 Part 2, thus preventing the ingress of harmful or flammable gases, liquid, smoke, fire and vermin.

5.2 Separation of Cables

- 5.2.1 Cables shall be classified as follows:

Table 2 Cable Classification

	AC	DC
High Voltage	> 1000 Vrms	> 1500 V
Low voltage (power, control, small power and lighting)	50–1000 Vrms	120–1500 V
Extra-low voltage (signal/instrument, data transmission and telecommunication)	< 50 Vrms	< 120 V

- 5.2.2 Except for reasons of electromagnetic compatibility, where larger separation will be required, the minimum separation distance between cables of different classifications shall be according to the following table.

Table 3 Separation distance

Separation (mm)	Extra Low Voltage	Low Voltage	Other Services (Above Ground)	Other Services (Below Ground)
Extra Low Voltage	-	As specified	150	500
Low Voltage	As specified	2 x cables above ground 100mm below ground	150	500
High Voltage Cables	500	300	300	500
Other Services (Above Ground)	150	150	-	-
Other Services (Below Ground)	500	500	-	-
Note:				
1. The above figures need not to apply to the short lengths of cables near the equipment to which the cable are connected. 2. Clearances to power lines are excluded from above table as they are covered by the Electrical Machinery Regulations. Furthermore, clearances to traction lines are subject to the regulations of the relevant railway authorities.				

- 5.2.3 The figures specified in the table above do not apply to cables that are installed in separate metal enclosures and/or cables on cable support systems (cable trays/ladders) that are separated with conductive partitions, provided such partitions are electrically bonded to earth.
- 5.2.4 Notwithstanding above, cables of different classifications and/or purpose (e.g. data, audio or power), shall not be installed in the same duct or wireway, and the minimum separation distance shall be kept even when their ducts or wireways are bonded (since radio frequency interference may then still be exhibited).
- 5.2.5 When cables have to cross, the crossing shall be at right angles.

5.3 Cable Trenches in Ground

5.3.1 General

- The proposed trench route shall be surveyed for the presence of underground cables and/or services before digging commences.
- The site shall be preserved as far as possible. Only the minimum of trees, shrubs, rocks, etc. shall be removed and cleared for the cable route.

- c) Where surplus material has to be disposed of, the Contractor shall remove it from site and dispose of it in a location of his choosing in accordance with statutory environmental regulations.

5.3.2 Excavation

- a) The cable trench shall be excavated along the routes indicated on the relevant drawings.
- b) Should the Contractor, during the excavation operations, come across obstacles (or other interferences, e.g. soil drenched with hydrocarbon-based solvents such as spilt oil, which could adversely affect cable insulation), the Contractor shall report the matter to the Engineer, who shall then advise an appropriate course of action.
- c) Trenches shall be dug to within the dimensional tolerances given by SANS 1200, parts DB and LC.
- d) Where the Contractor cannot excavate by means of machines, due to limited access and the proximity of other services, excavations shall be by hand.
- e) The bottom of the trench shall be level and shall follow the contours of the final ground level. Where the excavation is in excess of the required depth, the excavation shall be backfilled and compacted with suitable material to the required depth.
- f) The Contractor shall trim the trenches and clean up the bottom of the trenches after he has completed the required excavation.
- g) The Contractor shall remove all sharp projections, which could damage the cable where the trench is excavated through rocky formations, and shall remove all loose rocks, material, etc. from the bottom of the trench.
- h) No excavated material shall be left closer than 300 mm from the side of the excavation.
- i) Once the excavations for cable trenches have been completed, the Contractor shall give the Engineer one working day notice to inspect the trench and to be present when the measurements are made.
- j) The Contractor shall maintain the excavation in a good condition, free of water, mud, loose ground, rocks, stones, gravel and other strange material until the cables are installed.

5.3.3 Installation of Cables Directly in Ground

- a) Dimensions of trenches for the installation of cables directly in ground
- b) Trenches shall be excavated as follows:

Table 4 Excavation of trenches

	Width	Depth
Telecommunication Cable	450 mm	650 mm
LV Cable	450 mm	650 mm

- c) However, the following minimum clearances shall be maintained:

Table 5 Minimum clearances

	Vertical	Horizontal
Data and Telecom Cables	300 mm	300 mm
Water pipes	300 mm	300 mm
Sewer pipes	300 mm	800 mm
Storm water pipes	300 mm	600 mm
LV cables on same route	100 mm	One cable diameter of larger cable

- d) Where a cable will cross over other services, the cable shall not be installed at a depth less than 600 mm below ground level, and if this is not possible the cable shall be installed underneath the other service and shall be protected in the prescribed manner by means of concrete slabs. The depth of the cable shall be maintained for one metre on either side of the crossing.
- e) If it is not possible to cross over or underneath a service in the prescribed manner, the matter shall be referred to the Engineer for a decision.
- f) Where more than one cable need to be installed in a trench, the width of the trench shall be increased with a distance equal to the clearance required.

5.3.4 Sand bed and sand bed cover for cables

- a) A sand bed layer of soft soil shall be installed and levelled at the bottom of each trench after the trench has been approved by the Engineer, and prior to cable laying.
- b) If the excavated material is not suitable for the sand bed layer, then suitable soil shall be imported for this purpose. Quarried sand, man-made sand, sand clay and loam is usually suitable; sea sand, river sand, clay, chalk, unmixed ouklip, peat and mine sand may not be used. The cost of importing shall be included in the price for the excavation.
- c) The minimum thickness of the sand bed layer shall be 50 mm.
- d) If the soil for the sand bed and sand cover has to be sifted, a sieve with holes not larger than 6 mm shall be used.
- e) The cable shall, after the completion of the trench, be laid as soon as possible so that the trench can be backfilled.
- f) The sand bed cover for LV cables shall be 150 mm thick, of similar soil and shall be placed directly after the cable(s) has been inspected by the Engineer.
- g) Only one cable shall be laid at a time and the Contractor shall take precautions that the cables which are already installed are not damaged.

5.3.5 Laying of cables

- a) Cable rollers shall be used when cables are drawn into trenches. The cable rollers shall be placed so that the cable does not touch the bottom or the sides of the trench.
- b) If the Contractor intends using a winch to draw the cable into the trench, a cable stocking shall be used or the draw wires shall be soldered to the cable, such that the tension is exerted on all the cores, lead sheath and/or steel wire armouring at the same time.
- c) The maximum tension on a cable during laying operations shall not exceed the value specified by the manufacturer.
- d) Sufficient lengths of cable shall be left at the beginning and end of the cable routes to allow for the termination of the cables. The Contractor shall take the necessary precautions to protect the cable ends until they are terminated. The cable ends shall be sealed by means of lead or heatshrink sealing caps to ensure that the cable is waterproof.
- e) Where cables are drawn through sleeves, care shall be taken that they are not kinked or excessively bent.
- f) The Contractor shall keep accurate records of each length of cable laid. The following information shall be recorded:
 - i) Cable drum number
 - ii) Size of cable

- iii) Where the cable has been laid, i.e. the starting and finishing points
- iv) Length of cable
- v) Date laid
- g) The Contractor shall be liable for the repair of cables due to the faulty manufacture, should this information not be recorded directly after the cable has been laid.
- h) The Engineer shall inspect all cable trenches before backfilling to ensure that the laying of cables complies with the specification.

5.3.6 Backfilling of trenches

- a) When the cable has been laid, inspected and approved and the sand bed cover has been installed, the trench shall be backfilled with soil containing not more than 40 % rock or shale which shall be able to pass through a 100 mm sieve and which is approved by the Engineer.
- b) Where more than 40 %, but less than 70 %, rock occurs, the Contractor shall replace the rock with imported soil. However, should more than 70% rock occur then all the backfilling material shall be imported.
- c) The Contractor may import further stone-free material to the site or sieve the excavated material for sand bedding and cover but payment shall only be compensated for the actual quantity of imported material required as determined by the Engineer. The quantity of imported material required shall be calculated from the nominal trench width.
- d) The excavated material shall be backfilled in layers of 150 mm and shall be well compacted and consolidated to 90 % MOD AASHTO. Where the Engineer deems necessary, the Contractor shall use a mechanical vibrator to compact the trench.
- e) The Contractor shall maintain the completed sections of the cable trench in a proper safe condition for the duration of the contract. The Contractor shall refill and compact the trench where subsidence occurs.
- f) After completion of the work the route of the cable shall be neatly finished off and cleared. All stones bigger than 25 mm, as well as all loose organic material and rubble, shall be removed.
- g) Electrical warning tape, consisting of two tapes laid side-by-side and overlapping (such that their combined width is 150 % of a single tape width), shall be installed on all cable routes (LV and MV), 200 mm above the top cable layer. Where a cable route exceeds 600 mm in width, multiple warning tapes shall be run, in such a way that the space between adjacent warning tapes does not exceed 150 mm.

5.3.7 Installation of concrete slabs

Where cables cross other services such as water pipes, sewage pipes and other cables, or where the chance exists that the cable may be damaged as a result of excavation by others, the cable shall be protected by means of reinforced concrete slabs. The slabs shall protect the cable for a distance of 500 mm on either side of the crossing.

5.4 Cable Sleeves

5.4.1 General

- a) The construction of sleeves, draw pits and associated earthworks shall be in accordance with SANS 2001-DP3.
- b) Sleeves shall be PVC unless otherwise specified.


- c) The sleeves shall have a minimum wall thickness of 5 mm and mass not exceeding 45 kg per sleeve length.
- d) Where a change of direction is required, draw pits shall be constructed. Bends may only be used where prior approval has been granted by the Engineer. Where such approval has been granted, the maximum angle of a single bend in a sleeve shall be:
 - i) 45°, when all cables have a diameter less than 35 mm; or
 - ii) 22.5°, where any cable has a diameter greater than 35 mm.
- e) All bends shall be of the long radius type.

5.4.2 Method of Laying

- a) In order to facilitate future location of the sleeves, they are to be installed strictly in accordance with the relevant drawings.
- b) The Contractor shall select the number and/or dimensions of sleeves such that an additional cable, of outside diameter equal to 20 % of the sum of the outside diameters of the installed cables, can be pulled into the sleeve at a future date. Under roadways, this spare capacity shall be 50 %. Notwithstanding above requirement, a minimum of two sleeves shall be installed under all roadway crossings.
- c) When installed beneath roads, there shall be a minimum of 750 mm of cover above the crown of the sleeve, and the sleeve shall be extended to 1,5 m on either side of the road surface or kerb face.
- d) Where sleeves are installed during road construction, the sleeve positions shall be marked with the letters "E" or "ESC" for electrical, and "TEL" for telecommunication sleeves, cut or cast into the concrete of the kerb (or concrete marker, should the road be without kerbs). The grooved letters shall also be painted red, to facilitate easy identification.
- e) The sleeves shall be laid straight to within the dimensional tolerances given by SANS 1200 part LC.
- f) After installation, all foreign matter in the pipe shall be cleared.
- g) The sleeves shall be sealed with PVC plugs to prevent the entry of sand before backfilling.
- h) Precautions shall be taken to prevent damage to the sleeves during future construction activities.
- i) All sleeves shall be left with an 8 mm diameter nylon draw wire, or draw wire to SANS 2001-DP3, in place, anchored at each end.

5.4.3 Bore and Sleeve Jointing

- a) The bore shall be accurate, smooth and without surface cracks, and the inside edges edged or rounded.
- b) The edging or rounding shall be such that no ridge is formed when two sleeves are joined.
- c) A suitable slip collar, or other simple device, shall be provided to maintain the 5 mm spacing after the installation of the sleeves.
- d) Joints shall be carried out with suitable couplings to prevent movement between pipe ends.
- e) Joints shall be flexible enough to allow angular adjustments of up to 5° between adjacent lengths of sleeves during installation and afterwards to allow for subsequent subsidence of the ground.

- 
- f) The joints need not be watertight, but shall stop sand and other materials entering the sleeves.

5.4.4 Draw pits and masonry

- a) Where they are to be constructed in residential or commercial zoned areas, and where part of the draw pit will be visible above ground, the masonry units to draw pits shall be FBS (face brick standard). All other draw pit builds shall utilize solid concrete units.
- b) Draw pits covers shall be of cast iron manufacture, or as specified in the particular specification.



6. MARKING AND LABELLING OF CABLES

6.1 Low Voltage Cables

- 6.1.1 Conductors and/or cables shall be identified at both ends by cable markers, consisting of plastic sleeves with pre-printed, legible and indelible alpha/numeric element inserts. The plastic sleeves shall fully encircle the conductor and/or cable. The markers shall be suitable for the intended environment, for instance, UV resistant where installed in sunlight, etc. Reference character sizes shall not be less than 3 mm high.
- 6.1.2 The colours of conductor PVC insulation shall comply with SANS 10142-1, par. 6.3.3. The colours of conductors for sub-circuits shall as far as possible correspond with the colour of the supply phase. Except in the case of multi-way switching, the colour of a conductor may not change at any point along its run, starting from its point of origin at a circuit breaker inside the switchgear assembly. In other words, where loop wiring is employed, the colour of conductor insulation shall be the same throughout the circuit.

7. DRAWINGS AND DOCUMENTATION

7.1 General

7.1.1 All drawings, information, and documentation shall be in English, and each item shall be identified with:

- a) The Client's name and contact details
- b) Client's project / scheme / contract reference title and numbers
- c) The Engineer's name and contact details
- d) Engineers reference numbers
- e) Contractor's work / contract / order references

7.1.2 Drawings for acceptance shall be provided on A4 or A3 paper copies as specified.

7.2 Drawings for Approval

7.2.1 The following documentation and drawings shall be submitted to the Engineer prior to the installation of cables and wireways and before civil construction have started on the areas where cable routes are required:

- a) Cable route layout drawings showing
- b) Type of wireways
- c) Trenching
- d) Cable junction boxes

7.3 As-built Drawings

7.3.1 The Contractor shall produce detailed "as-built" drawings, clearly labelled as such, and consisting of 3 sets of drawings printed to their original size. Where the original drawings were larger than A3, 3 sets of printed drawings scaled to A3 size will be supplied. The A3 drawings will not have any information omitted from the printed area. The drawings will indicate the positions of the following:


- a) Wireways (e.g. trenches, conduit, cables ladder/trays, power skirting etc.);
- b) Cable routes (including any cable joints)
- c) General arrangement drawings
- d) Single Line Diagrams

7.4 Operating and Maintenance Manual

7.4.1 Three Operation Manuals, three Maintenance Manuals and three Certification copies shall be provided for all equipment supplied. The manuals shall be in A4 format.

7.4.2 The operating and maintenance manuals shall include at least the following:

- a) A schedule of installed components and equipment, containing the following information:
 - i) Manufacturers name and contact details
 - ii) Circuit number (DB name, circuit breaker e.g. DB01-CB08); and

- 
- iii) Function (e.g. switching lighting circuit DB03-L1)
 - b) A schedule of all installed cables, with the following information:
 - i) Circuit number (DB name, circuit breaker e.g. DB01-CB08)
 - ii) Size
 - iii) Installed length; and
 - iv) Function (e.g. "Feeding Submersible pump IW-SP-01")
 - c) Description and details of:
 - i) Detailed description of the function of all operator controls
 - ii) Procedures for fault finding
 - iii) Maintenance instructions for all components and including repair, overhaul, change-out and installation procedures
 - iv) Inspection schedules; and
 - v) Spare parts information and recommended spares

8. TESTING AND COMMISSIONING

8.1 General

- 8.1.1 The installation shall be inspected and tested in accordance with SANS 10142-1.
- 8.1.2 Inspection and testing shall only be performed by personnel with approved, current qualifications. The Contractor shall provide qualified personnel for the supervision for all inspection and testing activities.
- 8.1.3 The Contractor shall provide all necessary safety equipment and test instruments. All test instruments shall comply with SANS 61010 and have an up-to-date test and calibration certificate.
- 8.1.4 The Contractor's safe working arrangements shall comply with the safety management systems and procedures prevailing on site. Where there may be a risk of injury to personnel, the Contractor shall submit a risk assessment and method statement for approval, prior to starting work.
- 8.1.5 Unless otherwise specified in the Particular Specification, all inspection and test results shall be recorded using proforma documentation (test certificates and schedules) complying with SANS 10142-1.
- 8.1.6 The Contractor shall make provision for all inspection and testing activities to be witnessed. Unless otherwise specified in the Particular Specification, the period of notice for witness testing shall be 5 working days.
- 8.1.7 Where most of the inspection and testing activities are not witnessed, the Contractor shall allow for 10 % of the inspection and testing activities to be repeated for witness testing.
- 8.1.8 If there is a requirement for additional inspection and test activities to be performed as part of the commissioning process, this shall be specified in the Particular Specification.
- 8.1.9 Unless otherwise agreed by the Employer, no part of the installation shall be commissioned until all defects or omissions revealed by inspection and testing have been rectified. Where a defect or omission renders all or part of the installation unsafe for use, the Contractor shall take approved precautions to ensure that no part of the installation can be commissioned.

8.2 Test Sequence

8.2.1 Inspections before testing:

Before testing, inspections shall be performed to verify:

- a) All equipment and material is of the correct type and complies with applicable SANS and IEC standards
- b) All parts of the installation are correctly selected and erected
- c) No part of the installation is visibly damaged or otherwise defective
- d) The installation is suitable for the environmental conditions; and
- e) The installation complies with this Specification

8.2.2 Testing of Installation

On satisfactory completion of the inspections specified in 8.2.1 the following tests shall be undertaken in the sequence listed as per SANS 10142-1:



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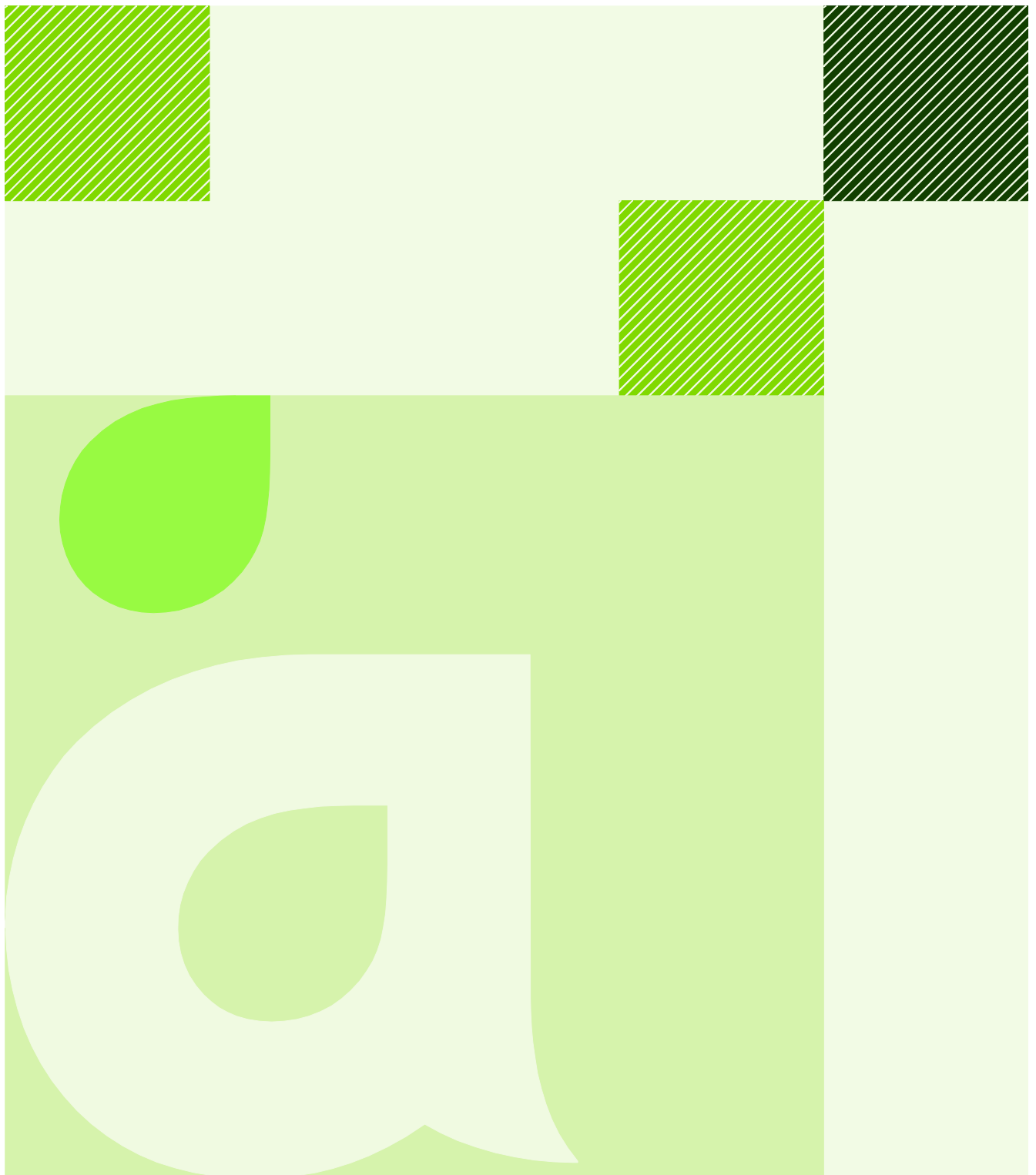
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1. SCOPE

1.1 Application

- 1.1.1 This document specifies the standard requirements for the design, installation, testing and commissioning of electrical installations operating on voltages up to 1 000 Volts AC / 1 500 Volts DC.
- 1.1.2 The primary intention of this specification is to ensure the provision of an electrical installation, which has been designed and constructed to ensure safe, reliable, operation and to facilitate safe inspection, testing and maintenance.
- 1.1.3 Note, however, that this specification only covers such installations (or sections of installations) that are covered by SANS 10142-1. Note also that certain provisions of this specification are inappropriate for direct application to installations where additional measures (such as earthing, intrinsic safe equipment, etc.) are required by SANS 10142-1 and SANS 10108 (i.e. medical and hazardous locations). For these types of installations, thorough reference must be made to the relevant statutory documentation.

1.2 Electrical System Characteristics

- 1.2.1 The design of the installation shall comply with SANS 10142-1.
- 1.2.2 The design of the installation shall consider the following supply characteristics:
 - a) Voltage, frequency and number of phases
 - b) Maximum prospective short circuit current (phase to phase and phase to neutral)
 - c) Type of system, e.g. TN-S, TN-C-S
 - d) Maximum earth loop impedance of the earth fault path external to the installation
 - e) Type and rating of the cut-out or switch device
 - f) Load capability of the supply source, particularly the effects on the supply voltage of the starting of new equipment and any fault contributions from new equipment
- 1.2.3 The installation of protective devices shall be correctly co-ordinated within the installation and with respect to existing installations. Discrimination studies shall be performed to validate the co-ordination of the installation.
- 1.2.4 All equipment which requires operation or attendance by a person, or requires cleaning or maintenance in service, shall be constructed and installed to allow adequate and safe means of access and adequate working space for such activities. Similarly, the positioning of equipment shall not impede access to, or working space at, non-electrical equipment and services for operation and maintenance activities.
- 1.2.5 The installation shall be suitable for access and use by electrically unskilled persons.
- 1.2.6 Where additions or alterations to an existing installation are to be performed, the rating and condition of existing equipment, including that associated with the supply, shall be verified to confirm its suitability to carry any additional load. The earthing and equipotential bonding arrangements shall also be verified. No addition or alteration shall have an adverse effect on the existing installation.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification identifies the Employer's standard modifications and requirements which shall be applied to the statutory and recognised standards. The detailed specification of the project or site-specific requirements will be found in the Particular Specification and its accompanying Technical Data Sheets, which shall be read in conjunction with this Specification.
- 2.1.2 Any items not specifically detailed in this Specification, which are necessary to provide a safe and fully operational working system, shall be deemed to be included.
- 2.1.3 The Contractor shall operate an auditable quality assurance procedure covering the design, construction, inspection and testing of the installation.

2.2 Regulations, Specifications and Standards

- 2.2.1 The design, construction, inspection and testing of the installation shall comply with all relevant Statutory Regulations and Directives including:

- a) Occupational Health and Safety Act (Act 85 of 1993)
- b) Construction Regulations 2003 issued in terms of Section 43 of the Act
- c) Local Fire Regulations; and
- d) Regulations of the Local Supply Authority

and the latest editions (current at the time of Tender) of all relevant South African National Standards, as well as International Standards, including but not limited to:

Table 1: Reference Standards

Standard Number	Description
SANS 121	Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
SANS 156	Moulded-case circuit-breakers
SANS 164	Two-pole and earthing-pin plugs and socket outlets
SANS 475	Luminaires for interior lighting, streetlighting and floodlighting - Performance requirements
SANS 767	Earth leakage protection unit
SANS 950	Unplasticized polyvinyl chloride rigid conduit and fittings for use in electrical installations
SANS 1063	Earth rods, couplers and connections
SANS 1085	Wall outlet boxes for the enclosure of electrical accessories
SANS 1088	Luminaire entries and spigots
SANS 1091	National colour standards of Paint
SANS 1195	Busbars
SANS 1213	Mechanical cable glands
SANS 1239	Plugs, socket-outlets and couplers for industrial purposes
SANS 1266	Ballasts for discharge lamps (excluding tubular fluorescent lamps)
SANS 1411	Materials of insulated electric cables and flexible cords
SANS 1431	Weldable structural steels

Standard Number	Description
SANS 1507	Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3 300 V)
SANS 1700	Fasteners
SANS 1777	Photoelectric control units for lighting
SANS 1783	Sawn softwood timber
SANS 1973	Low-voltage switchgear and controlgear Assemblies
SANS 10155	Accuracy in buildings
SANS 10199	The design and installation of earth electrodes
SANS 10225	The design and construction of lighting masts
SANS 10177	Fire testing of materials, components and elements used in buildings Part 2: Fire resistance test for building elements
SANS 10142-1	Wiring of Premises Part 1: Low Voltage Installations
SANS 10400	The application of the National Building Regulations
SANS 60269	Low-voltage fuses
SANS 60309	Plugs, socket-outlets and couplers for industrial purposes
SANS 60529	Degrees of protection provided by enclosures (IP Code)
SANS 60614-2	Conduits for electrical installations - Particular specification for conduits
SANS 60669	Switches for household and similar fixed-electrical installations
SANS 60947	Low-voltage switchgear and controlgear
SANS 61000	Electromagnetic compatibility (EMC)
SANS 61010	Safety requirements for electrical equipment for measurement, control, and laboratory use
SANS 61048	Auxiliaries for lamps - Capacitors for use in tubular fluorescent and other discharge lamp circuits - General and safety requirements
SANS 61238	Compression and mechanical connectors for power cables for rated voltages up to 30 kV(Um = 36 kV)
SANS 61643	Low-voltage surge protective devices
Other Standards	Description
ARP 035	Guidelines for the installation and maintenance of street lighting
BS 88	Specification of supplementary requirements for fuses of compact dimensions for use in 240 / 415 V industrial and commercial electric installations
IEC 157	Low voltage switchgear and control gear
IEC 408	Low voltage air-break switches, air-break disconnectors, air-break switch disconnectors and fuse combination units
IEC 12373	Aluminium and aluminium alloys. Anodizing. Method for specifying decorative and protective anodic oxidation coatings on aluminium
IEC 50086	Conduit systems for cable management
IEC 60898	Specification for circuit-breakers for overcurrent protection for household and similar installations

2.2.2 Standards are often tailored to the conditions of their country or origin (in terms of permissible voltages, expected ambient temperatures, etc.). Therefore, and unless normatively referenced to the contrary in a Standard of higher precedence, the decreasing order of precedence of Standards shall be:

- a) South African National Standards (SANS, VC, etc.)

- 
- b) South African Sectoral Standards and Specifications (NERSA, CKS, ARP, NRS, PIESA, etc.)
 - c) ISO Standards
 - d) IEC Standards
 - e) Harmonized British Standards (BS EN)
 - f) Other Harmonized European National (EN) Standards (CEN, CENELEC, ETSI)
 - g) Non-Harmonized British Standards (BS)
 - h) Other international standards

2.2.3 Where Standards of the same order are not in agreement with each other, the Standard with the most rigorous requirements shall apply.

2.2.4 The installation shall also comply with:

- a) This Specification, including all Technical Data Sheets; and
- b) Any documentation issued by, or on behalf of, the Employer in respect of the Installation.

3. INSTALLATION OF CABLE SUPPORTS

3.1 Cable Trays, Mesh and Ladders

3.1.1 General

- a) Cable management systems (cable trays, cable ladders and cable mesh) shall be selected and installed strictly in accordance with their manufacturer's guidelines, with a safety factor of 1.5 after taking into account maximum permissible loading and all external factors (not limited to wind, snow and thermal expansion). Upon demand to do so, the Contractor must furnish all data and calculations he used to derive the type and spans of the systems to the Engineer.
- b) Notwithstanding above, the deflection of a cable management system due to installed cable weights shall be, in accordance with IEC 61537, limited to 1/100th of the span.
- c) Except where it is to be installed in locations with corrosive atmospheres, cable management systems shall be manufactured of galvanized and/or epoxy-powder coated steel. In locations with corrosive atmospheres, systems shall be manufactured from stainless steel (316 Marine Grade) or aluminium.
- d) All clamps, clips, hinges screws, bolts, nuts and support fittings used for fastening cable trays or cables shall be of the same material as the cable management system itself.
- e) Over and above the requirements of SANS 10142-1, all cable tray and ladder systems that will support telecommunication and / or control wiring shall be bonded in accordance with NRS 083-2 (gives details of bonding methods that provide enhanced protection against the effects of electromagnetic cross-interference).
- f) Cable management systems shall be selected and installed such that spare capacity (weight as well as height and width) of 20 % will be available for the addition of future services (the cable management system to still exhibit a 1.5 safety factor after services were added).

3.1.2 Cable Trays

- a) All cable trays shall be of the heavy duty, increased upstand ("siderail"), type.
- b) Metal cable trays shall be manufactured from base-perforated (in excess of 30 % of the surface area, in accordance with SANS 10142-1, in other words, class D according to Table 4 of IEC 61537) rolled steel. Metal trays manufactured to the following standards shall be used:
 - i) Less than 150 mm wide: 1,2 mm minimum thickness with 12 mm minimum upstand
 - ii) 150 mm to 450 mm: 1,2 mm minimum thickness with 19 mm minimum upstand
 - iii) Above 450 mm (heavy duty): 2,5 mm minimum thickness with 76 mm upstand
- c) The edges of cable trays are to be turned up on both sides to improve rigidity (return flange cable tray), and, where necessary, the sides of trays shall be reinforced with galvanised steel angles, minimum 25 x 25 x 3 mm, with 25 x 3 mm cross-braces at 600 mm centres.
- d) Cable trays shall be hot-dip galvanised only after the perforation and bending processes have been completed.

3.1.3 Cable Ladders

- a) Metal cable ladders shall have side rails with 2 mm minimum thickness. Cross rungs shall be spaced at maximum intervals of 300 mm (measured between the centres of rungs). Where cables of 10 mm² or smaller are installed on cable ladders, the spacing of cross rungs shall be reduced to 125 mm.
- b) Cable ladders consisting of slotted metal rails which accommodate plastic or metal cable binding bands may be used in vertical cable runs against walls, etc. These cable

ladders will be considered in horizontal cable runs for small cables for communication and control wiring only after approval by the Engineer.

3.1.4 Cable Tray and Ladder Connections

- a) Cable tray and ladder connections shall be suited to and of the same manufacture as the linear sections that they connect.
- b) The dimensions of these connections shall correspond to the dimensions of the linear sections to which they are connected.
- c) The radius of all bends shall be 1 m minimum. The inside dimensions of horizontal angles or connections shall be large enough to ensure that the allowable bending radii of cables are not exceeded.
- d) Sharp angles shall be 45° mitred.

3.1.5 Installation of Cable Trays, Cable Ladders and Cable Mesh

- a) The spacing between tiers of ladders, trays and/or mesh shall be 300 mm minimum. Furthermore, they shall be installed such that a minimum separation of 300 mm exists between ceilings and the top of a tray or ladder (where the latter is installed horizontally) and 50 mm between the nearest sides of trays or ladders and the finished surfaces of walls, floors and ceilings for other configurations.
- b) Fixing materials shall be compatible with cable management system materials, and offer resistance to corrosion.
- c) Cuts in trays shall not pass through perforations, except where practically impossible to implement.
- d) Cable trays and mesh shall be mounted with a minimum air gap of 25 mm between the underside of the tray and the mounting surface.

3.1.6 Installation of Cables on Cable Trays, Ladders and Mesh

- a) Cables shall be supported to avoid damage during installation, prior to dressing and fixing.
- b) Depending on the overall diameter, single cables and groups shall be secured according to the following.

Table 2: Installation of cables

	Overall Diameter
Nylon UV Protected Cable Ties	< 35 mm
Propriety cable clamps	> 35 mm

- c) In outdoor applications, where the installation maybe subject to ultra-violet light, PVC covered aluminium tape shall be used instead of nylon cable ties.
- d) Cables installed in groups shall be installed in straight lines and not cross over each other, except where single core cables need to be transposed.
- e) Where cables exit ladders, trays or mesh, the latter shall be formed or covered with PVC to ensure a smooth surface.
- f) Where single core cables are installed in trefoil formation, trefoil cable clamps shall be used.

4. DRAWINGS AND DOCUMENTATION

4.1 General

4.1.1 All drawings, information, and documentation shall be in English, and each item shall be identified with:

- a) The Client's name and contact details
- b) Client's project / scheme / contract reference title and numbers
- c) The Engineer's name and contact details
- d) Engineers reference numbers
- e) Contractor's works / contract / order references.

4.1.2 Drawings for acceptance shall be provided on A4 or A3 paper copies as specified.

4.2 Drawings for Approval

4.2.1 The following documentation and drawings shall be submitted to the Engineer prior to the installation of cables and wireways and before civil construction have started on the areas where cable routes are required:

- a) Cable route layout drawings showing
- b) Type of wireways
- c) Trenching
- d) Cable junction boxes

4.3 As-built Drawings

4.3.1 Detailed "as-built" drawings, clearly labelled as such, and consisting of 3 sets of drawings printed to their original size, and, where the original drawings were larger than A3, 3 sets of drawings printed (with reduced scaling, but without omitting any information from the printed area), to A3, shall be provided by the Contractor, indicating positions of the following:


- a) Wireways (e.g. trenches, conduit, cables ladder/trays, power skirting etc.); and
- b) Cable routes (including any cable joints)
- c) General arrangement drawings
- d) Single Line Diagrams

4.4 Operating and Maintenance Manual

4.4.1 Three Operation Manuals, three Maintenance Manuals and three Certification copies shall be provided for all equipment supplied. The manuals shall be in A4 format.

4.4.2 The operating and maintenance manuals shall include at least the following:

- a) A schedule of installed components and equipment, containing the following information:
 - i) Manufacturers name and contact details
 - ii) Circuit number (DB name, circuit breaker e.g. DB01-CB08); and
 - iii) Function (e.g. switching lighting circuit DB03-L1)
- b) A schedule of all installed cables, with the following information:
 - i) Circuit number (DB name, circuit breaker e.g. DB01-CB08)
 - ii) Size

- 
- iii) Installed length; and
 - iv) Function (e.g. "Feeding Submersible pump IW-SP-01")
 - c) Description and details w.r.t:
 - i) Detailed description of the function of all operator controls
 - ii) Procedures for fault finding
 - iii) Maintenance instructions for all components and including repair, overhaul, change-out and installation procedures
 - iv) Inspection schedules; and
 - v) Spare part information and recommended spares

5. TESTING AND COMMISSIONING

5.1 General

- 5.1.1 The installation shall be inspected and tested in accordance with SANS 10142-1.
- 5.1.2 Inspection and testing shall only be performed by personnel with approved, current qualifications. The Contractor shall provide qualified personnel for the supervision for all inspection and testing activities.
- 5.1.3 The Contractor shall provide all necessary safety equipment and test instruments. All test instruments shall comply with SANS 61010 and be covered by a current test and calibration certificate.
- 5.1.4 The Contractor's safe working arrangements shall comply with the safety management systems and procedures prevailing on site. Where there may be a risk of injury to personnel, the Contractor shall submit a risk assessment and method statement for approval, prior to starting work.
- 5.1.5 Unless otherwise specified in the Particular Specification, all inspection and test results shall be recorded using proforma documentation (test certificates and schedules) complying with SANS 10142-1.
- 5.1.6 The Contractor shall make provision for all inspection and testing activities to be witnessed. Unless otherwise specified in the Particular Specification, the period of notice for witness testing shall be 5 working days.
- 5.1.7 Where most of the inspection and testing activities are not witnessed, the Contractor shall allow for 10 % of the inspection and testing activities to be repeated for witness testing.
- 5.1.8 If there is a requirement for additional inspection and test activities to be performed as part of process commissioning, this shall be specified in the Particular Specification.
- 5.1.9 Unless otherwise agreed by the Employer, no part of the installation shall be commissioned until all defects or omissions revealed by inspection and testing have been rectified. Where a defect or omission renders all or part of the installation unsafe for use, the Contractor shall take approved precautions to ensure that no part of the installation can be commissioned.

5.2 Test Sequence

5.2.1 Inspections before Testing


Before testing, inspections shall be performed to verify:

- a) All equipment and material is of the correct type and complies with applicable SANS and IEC standards
- b) All parts of the installation are correctly selected and erected
- c) No part of the installation is visibly damaged or otherwise defective
- d) The installation is suitable for the environmental conditions; and
- e) The installation complies with this Specification

5.2.2 Testing of Installation

On satisfactory completion of the inspections specified in 5.2.1, the following tests shall be undertaken in the sequence listed as per SANS 10142-1:

- a) Continuity of conductors
- b) Resistance of Earthing conductor

- 
- c) Continuity of ring circuits Earth fault loop impedance at main switch
 - d) Elevated voltage on supply neutral Earth Resistance
 - e) Insulation resistance
 - f) Voltage, main distribution board - no load
 - g) Voltage, main distribution board - on load
 - h) Voltage at available load
 - i) Operation of earth leakage units
 - j) Earth leakage test button
 - k) Polarity at points of consumption
 - l) Switching devices



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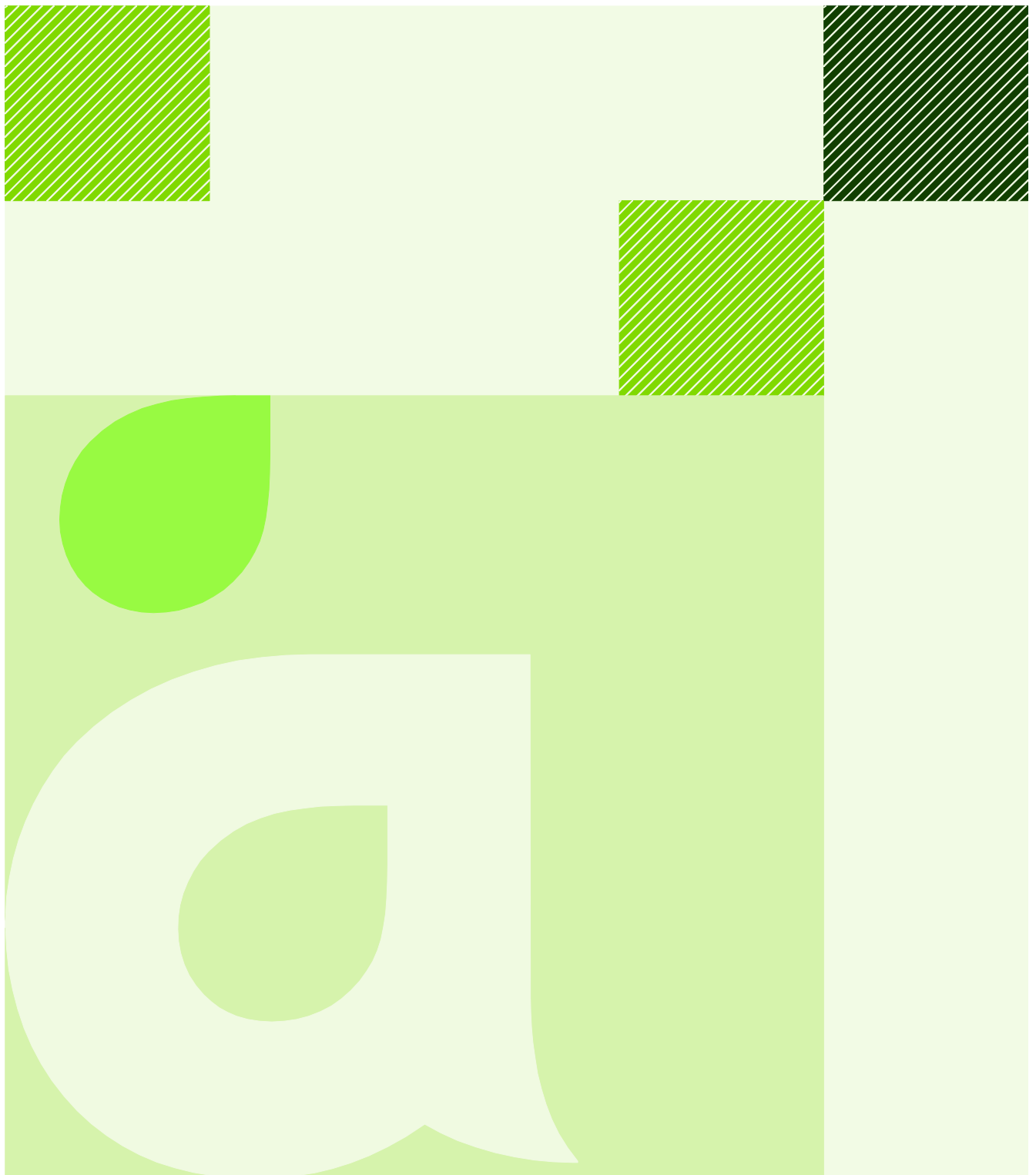
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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification defines the general requirements for the design, construction, supply, testing, installation and commissioning of Electronic Control & Instrumentation installations for Industry.

1.2 General Requirements

- 1.2.1 All Electronic Control & Instrumentation equipment shall be housed in dedicated control panels or enclosures conforming to the South African National Standard (SANS) for Control Gear as listed below.
- 1.2.2 The completed Assembly shall incorporate all components and equipment necessary to reliably achieve the functionality defined in the Project Specification and works or plant Control Philosophy.
- 1.2.3 All materials, components, and equipment used in the manufacture of the Assembly shall be new and unused, shall be of current manufacture, and shall be free from any defects or imperfections.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification contains standard amendments and requirements, which shall be applied to the referenced statutory and national standards. The project-specific requirements are provided in the Project Specification, which shall be read in conjunction with this Specification.
- 2.1.2 The design, construction, installation, inspection, testing and commissioning of the Assembly shall comply with all relevant statutory regulations, and the latest editions (current at the time of Tender) of all relevant South African National Standards.
- 2.1.3 The Manufacturer shall follow an approved, auditable quality assurance system covering the design, construction, programming, configuring, inspection and testing of the Assembly.

2.2 Statutory Requirements

- 2.2.1 The Assembly as manufactured, and as installed on site, shall comply with the following:
- a) Occupational Health and Safety Act of 1993
 - b) Manufacturer's specifications and installation instructions

2.3 Reference Standards

- 2.3.1 The Assembly and all its constituent components shall comply with the latest published edition of all relevant national standards, including the following:

Table 1 Reference Standards

SANS Number	Description
SANS 1973	Low-voltage switchgear and controlgear Assemblies
SANS 60204	Safety of machinery - Electrical equipment of machines
SANS 60439	Low-voltage switchgear and controlgear assemblies
SANS 61000	Electromagnetic compatibility (EMC)
SANS 61643	Surge Protection for Low-voltage AC and DC power supply systems, electronic systems, signalling systems and communication devices
SANS 62103	Electronic equipment for use in power installations
SANS 62305-4	Protection against lightning - Electrical and Electronic systems within structures
SANS 60950-1	Information Technology Equipment Safety - General Requirements
SANS 10142-1	The wiring of premises, Part1 - Low-voltage Installations

3. CONSTRUCTION REQUIREMENTS OF ELECTRONIC ASSEMBLIES

3.1 General

- 3.1.1 Electronic Assemblies shall be designed and constructed to facilitate inspection, cleaning, repair and maintenance and to ensure absolute safety during operation, inspection and maintenance. The Electronic Equipment manufacturer's requirements for enclosure cooling and ventilation of the equipment shall be adhered to at all times.
- 3.1.2 The arrangement of all circuit components / functional units shall be to the approval of the Engineer.

3.2 Enclosures

- 3.2.1 Assemblies shall be constructed of materials capable of withstanding the mechanical, electrical and thermal stresses to which it may be subjected and the environmental and operating conditions likely to be encountered in normal service.
- 3.2.2 All panels and enclosures shall be vermin and dust proof and the minimum degree of protection shall be:

Table 2 Minimum levels of ingress protection

Location	Description	Minimum rating
Indoor	Clean, dry areas (e.g. inside switch rooms or control rooms)	IP44 (doors closed) IP2X (inter-compartment & doors open)
Outdoor	Located outside of buildings in double clad outdoor weather proof enclosures	IP65 (doors closed) IP2X (inter-compartment & doors open)

- 3.2.3 Where heat is generated within the enclosure, it shall, where possible, be designed to dissipate naturally from the enclosure surface. Where this is not possible, ventilation openings shall be provided that maintains the highest practicable IP rating of the enclosure, subject to a minimum of IP42. Where cooling air is drawn into the enclosure, dust filters shall be provided.
- 3.2.4 Particular attention shall be given to the ventilation of outdoor mounted boards, to eliminate build-up of excessive heat inside the boards caused by solar radiation or internal heat generation. If the internal temperature rise is within 20 % of the upper scale of the manufacturers specification for the equipment during any time of the day or year, panel coolers shall be provided as detailed in the project Specification.
- 3.2.5 All the surfaces of the enclosure, and of its constituent equipment and components shall be suitably protected against the effects of any likely atmospheric corrosion present at the operating location.
- 3.2.6 Purpose-made gland plates shall be protected against corrosion by electro-plating, galvanising, or be made of stainless steel which shall not be painted.

3.3 Construction

- 3.3.1 Free-standing electronic enclosures shall be constructed from steel with a structural frame permanently clad with side plates, so as to provide a structure that is rigid with all doors and covers removed, and such that it will not deform during transportation or installation. The enclosure doors and covers shall themselves be suitably braced so as to be rigid and not deform or flex when fully equipped and handled.

3.3.2 The minimum metal thickness of the enclosure's constituent parts shall be as follows:

- a) External cladding: 2.0 mm
- b) Internal partitions: 1.6 mm
- c) Doors: 2.0 mm
- d) Gland plates and component mounting plates: 2.0 mm

3.3.3 Freestanding Assemblies shall be mounted on and bolted to a rigid hot-dip galvanised steel 100x50x6 mm channel iron base.

3.3.4 Wall mounted Assemblies shall be bolted to walls on concrete structures via a hot dip galvanise channel iron using spring nuts and washers with the channel iron bolted to the wall with concrete anchor bolts.

3.3.5 The maximum height of any Assembly (including its base) shall be 2100 mm above finished floor level. No equipment shall be installed higher than 1900 mm above finished floor height, neither shall any equipment, other than cable glands and inter panel control wiring be installed lower than 300 mm above finished floor level.

3.3.6 Enclosure single doors shall have vertical hinges mounted on their left hand side, be limited to 800 mm width, and all doors shall have an angle of opening that is limited to 95 degrees. Where specifically agreed with the Engineer, a compartment single door may be hinged on the right hand side if this is beneficial to the room and equipment layout. Panels wider than 800 mm shall be fitted with dual doors that shall open in wardrobe style, such that the second door is interlocked with the first.

3.3.7 Doors and any covers shall be fixed to the enclosure using captive bolt type fasteners, and each hinged door shall be capable of being removed, following disconnection of any electrical and earthing connections to components mounted on the doors. Compartment doors shall be provided with securing catches which can be locked with a padlock.

3.3.8 Doors shall include a full-length safety glass window with rubber gasket such that the internal electronic equipment status can be observed without opening the door. Where an HMI, pushbuttons, selector switch or indication lamps will be fitted to the door, the glass window will be placed below the equipment over the full remaining length of the door.

3.3.9 The Assembly shall be constructed for front and rear access unless otherwise specified in the Project Specification. Where the Assembly shall be designed for front access only; i.e. it shall be possible to gain access to every component, item of equipment, busbar and cable from the front (or for busbars, the top) of the enclosure; whether for maintenance or for replacement.

3.3.10 Fixings for components, component mounting plates, etc. shall not penetrate another compartment containing live parts. Only threaded fasteners shall be allowed and no components shall be fixed with rivets or self-tapping screws.

3.3.11 All components, wiring, labelling, etc., shall only be located within compartments on a removable mounting plate, and in such a manner that facilitates easy inspection, maintenance, or removal and replacement, and without necessitating the removal or dismantling of any other components or wiring, or the use of special tools.

3.3.12 All Assemblies shall make provision for have at least 15 % spare unequipped space complete with mounting rails and wire ways for future extensions.

4. INTERNAL WIRING AND FIELD CONNECTIONS

4.1 General

- 4.1.1 All wiring within the Assembly shall run directly between terminals, without any joints or other connections. Wiring shall be carried out using multistrand, single-core PVC-insulated copper conductor, 660/1 000 V grade (minimum), to SANS 1507, sized and derated where required for the currents to be carried. Single-strand conductor shall not be used and no conductor shall be less than 0.75 mm² cross-sectional areas.
- 4.1.2 Wiring shall be tinned if and as called for in the project Specification.
- 4.1.3 Field wiring connections will be identified using the field device tag references. This information will be provided by the Engineer, and the Contractor shall use these field identifiers when identifying the signal field terminations.
- 4.1.4 Wiring layout shall permit alterations to individual circuits without requiring shut down of the complete Assembly.

4.2 Wire ways inside Assembly

- 4.2.1 All wiring shall be routed in PVC cable trunking wire ways with snap-on covers and shall be sufficiently sized and properly placed in order to provide a neat and manageable internal wire routing system.
- 4.2.2 All wiring and cabling entering or leaving a compartment or passing through a partition shall do so via a permanently fixed PVC bush.
- 4.2.3 Wiring between components shall be:
 - a) carried out in a neat and systematic manner
 - b) contained in PVC trunking
 - c) run to panel doors in PVC spiral wrapping
- 4.2.4 Any wire containment system shall securely locate the wiring, and provide 25 % spare capacity on completion. Wire ways shall have furthermore sufficient space to enable the installation and removal of any wire without the need to remove any other wire, cable or component. Wire ways shall incorporate adequate facilities to locate and support the wires and cables.
- 4.2.5 Wiring on doors shall be similarly supported, and shall be provided with support and protection across the door to enclosure side wall transition, whilst permitting the door to be fully opened without straining the wiring. Wiring system accessories shall not be flame retardant and not deteriorate with heat.
- 4.2.6 Wiring shall be segregated according to need; circuits that enter the compartment without isolation shall be separately segregated and loomed with spiral wrapping and identified. Control circuits shall be wired in twisted pairs or screened cables, and together with data network cabling, shall be physically segregated from power circuits by barriers. Where lightning and/or surge protection measures have been implemented to protect individual circuits, these circuits shall be segregated from the wiring of other unprotected circuits.
- 4.2.7 Wire ways or chambers shall not contain any equipment or components.

- 4.2.8 Where field cables are terminated other than in the base of the enclosure, cable-ways or cable chambers shall be provided to transport the cables through the enclosure to the compartment or cable box at which they are glanded or terminated.

4.3 Gland Plates


- 4.3.1 All field cables and wiring shall enter the enclosure through gland plates, which shall be located so as to facilitate the spreading of cable cores.
- 4.3.2 Gland plates shall be rigidly supported and maintain the IP rating of the enclosure.
- 4.3.3 Gland plates for bottom access cabling shall be located at least 300 mm above the finished floor level and shall be an integral part of the construction of the enclosure.

4.4 Identification

- 4.4.1 All wires shall be identified at both ends using colour coded alpha-numeric ferrules within a compartment.
- 4.4.2 Where a circuit includes a PLC I/O point, the I/O point identification shall follow through from the PLC card to the first component within a remote compartment.
- 4.4.3 Components and wiring shall be installed such that the identification of every wire is clearly visible and readily accessible on completion of the Assembly installation at site. Horizontal wiring identifiers shall be read left to right, and vertical wiring identifiers shall be read bottom to top.
- 4.4.4 All conductors shall be identified in conformity with the approved circuit and connection diagrams. No number shall be used more than once in each panel except where electrically identical.
- 4.4.5 Wires/conductors shall have the same number on either end of the wire and all wires which are electrically identical shall have the same wire number.
- 4.4.6 Circuit wiring shall be coloured in accordance with the clients requirements as detailed in the Project Specification.

4.5 Termination

- 4.5.1 Wiring shall be terminated using crimped cable ends, lugs or any other approved method that is appropriate for the conductor size and type of termination. All of the strands forming the conductor shall be connected at the point of termination. Soldered connections shall only be used on electronic equipment where it is not practicable to use any other termination method.
- 4.5.2 All wiring entering or leaving a compartment shall do so via screw type terminal rails, with the exception of specialised signal or data circuits, which may be cabled directly to dedicated connections on electronic equipment located at the periphery of the component mounting plate.
- 4.5.3 No more than two wires shall be connected to any one side of a terminal. Where it is necessary to connect adjacent terminals together, proprietary jumper bars or combs shall be used.
- 4.5.4 Spare cable cores shall be terminated at both ends or tied back, but shall not be cut short.
- 4.5.5 All terminals shall be protected to IP2X, including stud type terminals; which shall be shrouded to achieve this rating.

- 
- 4.5.6 Terminals shall be segregated according to function and operating voltage; by grouping or by terminal rail mounted partitions or barriers and all circuit terminal rails shall include 10 % spare space.
 - 4.5.7 Terminals shall face the compartment door for ease of connection.
 - 4.5.8 Terminals shall be located and spaced so as to enable the easy disconnection and reconnection of conductors, whilst providing sufficient space for the looming and spreading of cable cores. Where practicable, the layout of terminal rails shall be such that cores from the same field cable are not split between non-adjacent groups of terminals.
 - 4.5.9 All wiring of external connections shall be brought out to individual terminals on a readily accessible terminal block.

4.6 Junction Boxes

- 4.6.1 Equipment and junction boxes shall be of steel, aluminium or GRP construction or as specified in the Project Specification.
- 4.6.2 All steel Junction Boxes shall be primed, undercoated and gloss finished with epoxy or polyurethane paint.
- 4.6.3 All boxes shall have a box name or number on the cover.
- 4.6.4 Junction Boxes for indoor use shall be at least IP 54 rated and Junction Boxes for outdoor use shall be at least IP 65 rated.
- 4.6.5 Junction boxes shall provide the facility to fully terminate the entire multi-core cable entering the box.
- 4.6.6 Junction Boxes which are exposed to the sun, shall be installed south facing otherwise with an additional shading cover.
- 4.6.7 Junction Boxes shall be mounted with their sides true vertical and horizontal.
- 4.6.8 Junction Boxes for instrumentation integral cables shall be of the round screw lid GRP or Aluminium type with two, three or four gland ports and shall be supplied fully equipped with screw terminals on a DIN rail inside and appropriate compression glands to fully gland and terminate the incoming and outgoing cables to maintain the required IP rating.


5. EARTHING

5.1 General

- 5.1.1 The complete electronic installation shall be earthed in accordance with the latest issues of the applicable South African National Standards (SANS) and any applicable bylaws of the local supply authority as well as any relevant client specific requirements as stipulated in the Project Specification.
- 5.1.2 The electronic installation shall incorporate a protective (power supply) earth system and a separate functional (instrumentation / data communications) earth system both of which shall be connected to the overall low-voltage installation's main earth system.
- 5.1.3 The Contractor shall familiarize himself with the Low-Voltage installation's earthing system at the plant or works (existing or installed by others) in order to tie the electronic earth system to the main earth system in compliance with the chosen earthing concept as defined in SANS 10142-1.
- 5.1.4 All functional earth conductors shall be insulated conductors providing a "clean earth" arrangement.

5.2 Earth Bars

- 5.2.1 Each Electronic Assembly shall include a separate protective Earth and functional earth bar. Earth bars shall:
 - a) be manufactured from high conductivity copper (tinned if and as called for in the Particular Specification)
 - b) be located in a safe and easily accessible position
 - c) have facilities for connection to the main incoming earth terminal (located in the LV switchroom / control room or at a local earth electrode system)
 - d) be rated and tested for the Assembly's expected maximum electrical supply fault current
 - e) be securely connected in each panel or cubicle with the protective earth bar bonded to the enclosure and the functional earth bar insulated from the enclosure
- 5.2.2 Provision shall be made for the connection of the following conductors to the fixed portions of the earth bars via drilled holes, cable lugs and fixing bolts:
 - a) electrical installation protective earth conductors internal and external to the Assembly
 - b) functional earthing conductors internal and external to the Assembly
 - c) equipotential bonding conductors internal and external to the Assembly
 - d) other equipment protective conductors external to the Assembly
 - e) an additional 2 off spare terminations
- 5.2.3 All metallic non-current carrying parts of the Assembly shall be bonded together and connected to the Assembly protective earth bar.
- 5.2.4 The following assembly parts shall be directly connected (bonded) to the protective earth bar by earthing conductors or braided straps with a minimum cross sectional area as defined in SANS 10142-1:


- 
- a) enclosure door (if it incorporates any equipment such as an HMI, pushbuttons, selector switches or indication lamps)
 - b) any removable electronic equipment covers
 - c) component / equipment mounting plates, rails and earth terminals
 - d) PLC / PCS and Instrumentation enclosure chassis plates
- 5.2.5 Surge protection earths; e.g. direct connections from lightning protection units. The following circuits shall be connected to the functional earth of the relevant assembly by earthing conductors with a minimum cross sectional area as defined in SANS 10142-1:
- a) 'clean' earths from instrumentation circuits and equipment
 - b) functional earths; e.g. from telecommunications equipment
- 5.2.6 Each Assembly's earth terminals or bars shall be separately connected directly back to the Assembly main earth bar with earthing conductors of a minimum cross sectional area as defined in SANS 10142-1.
- 5.2.7 For installations that include control rooms or computer rooms (housing Information Technology and Telecommunications equipment), the functional earth shall consist of an earthing busbar and/ or earth mat as directed by the Project Specification.
- 5.2.8 Earthing busbar design and sizing shall comply with Annexure N of SANS 10142-1 and be rated as stipulated in the Project Specification and Technical Data Sheets.
- 5.2.9 Computer and Control Room earth mats shall be designed taking into account the expected equipment operational frequency ranges and equipment densities according to SANS 61000-5 Part 2.
- 5.2.10 Each Electronic Assembly in the Control or Computer Room shall be bonded directly to the earth busbar or earth mat via the shortest route and the earth busbar and/ or mat shall be separately connected directly back to the Assembly main earth bar, all with insulated earthing conductors of minimum cross sectional area as defined in SANS 10142-1.
- 5.2.11 If specified in the Project Specification, separate earth bars or studs shall be provided for connecting equipment requiring an intrinsically safe earth directly to the main incoming earth terminal. If required, such earth bars or studs shall be located adjacent to the equipment requiring an intrinsically safe earth, as directed by the intrinsically safe equipment supplier.
- 5.2.12 Where zener diode safety barriers are contained within an Assembly, they shall be separately and directly connected to the main earth bar via double earthing conductors; These conductors shall be clearly identified as intrinsically safe earths.

5.3 Earth Electrode

- 5.3.1 Where a protective Earth Electrode does not exist or has NOT been installed as part of the Low-voltage installation by others, this contract shall include for the supply and installation of a suitable main earth electrode as stipulated in the Project Specification and the Engineering Standard SPE-EE-0010 "LV and MV Earthing".
- 5.3.2 A separate Electronic or "clean earth" electrode will not be accepted.

5.4 Earthing of Communication and Signal Cables

- 5.4.1 For the purpose of this specification, "communication" cables shall mean all data and network communication and transmission cables, and signal cables shall mean all instrument voltage or current loops and sensor cables.

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- 5.4.2 The “common” or “reference” conductor of all signal cables shall be connected to the protective earth of the Electronic Assembly in order to ensure the safety of the equipment as well as the signal's integrity.
 - 5.4.3 Communications cables shall be connected to the functional earth to protect them against the negative effects of electromagnetic, inductive and capacity coupling so that noise on cables is limited to an absolute minimum preventing communication faults from occurring.
 - 5.4.4 This shall be achieved by shielded (double screened) twisted conductor pair cables with the outer screen of all communication cables earthed with the aid of soldered termination and cable lugs at the source (electronic assembly) only. The route that the screened wire follows to the electronic assembly's functional earthing point shall be as short as possible.
 - 5.4.5 Where communications cables carry high frequencies (above 1 MHz) the screen shall be earthed to a parallel running functional earth conductor of minimum 2.5 mm² insulated copper conductor (or earth grid/ mat) in order to limit the effects of high frequency resonance.
 - 5.4.6 When communications or signal cables are installed where there is a significant risk of high frequency interference; (e.g. in signal circuits connected to equipment containing power electronics), they shall have their screens capacitively connected to earth as directed by the specific equipment supplier.

6. LIGHTNING AND SURGE PROTECTION

6.1 General

- 6.1.1 The complete Electronic installation shall be protected against transients, surges and induced interference from nearby electrical cables and / or equipment as well as mechanical equipment and related structures.
- 6.1.2 The protection shall ensure that the electronic equipment integrity is maintained and remains operational, or otherwise isolates the equipment from the transients, surges or interference in such a manner that it can be returned to operational use after the event.
- 6.1.3 Protection measures shall be provided as described below.

6.2 Earthing for Lightning and Surge Protection


- 6.2.1 The Lightning Protection System (LPS) shall be designed and selected to mitigate the expected lightning intensity on the site and as defined in the Project Specification.
- 6.2.2 Unless stated otherwise in the Project Specification, the Lightning protection system shall be assumed to be existing or installed by others under a separate Contract and the Electronic Assembly lightning protection measures shall tie into that system.
- 6.2.3 The Contractor shall familiarize himself with the system (existing or new) in order to tie into the system in the appropriate manner and as described in SANS 10142-1 and SANS 62305.
- 6.2.4 Proper bonding of all Electronic Assembly enclosures to the protective earth as described in Section 5.2 above, shall ensure protection against lightning induced electromagnetic surges impinging on the electronic assembly and all its internal components. All components supplied and installed within the Electronic Assemblies shall in any event be EMC compliant according to IEC 61000.
- 6.2.5 Proper shielding and bonding of communications and signal cable shields to the functional earth, as described in section 5.3 above, shall ensure protection against lightning induced electromagnetic surges impinging on data communications and signal cables to and from the Electronic Assemblies.
- 6.2.6 For the protection against lightning induced surges on power, communications and signal connections to and from the Electronic Assembly components, other assemblies and field devices, either isolation transformers, optical isolation, metal free fibre optic cabling or a system of coordinated surge protection devices (SPDs) connected to all conductors shall be used depending on the location of the equipment in the relevant lightning protection zones (LPZ), the expected surge intensities and the electronic equipment's impulse withstand ratings; all as defined in SANS 62305.
- 6.2.7 Where more than one SPD module is used at any one location or within any one Assembly, these shall be grouped together in one physical location.
- 6.2.8 The SPD modules shall be installed as close as possible to the Assembly's protective earth bar and shall be bonded to the protective Earth bar with a stranded copper conductor of minimum 6 mm² for Class II SPD (power) and 1 mm² for Class III SPD (signal and data).
- 6.2.9 Each surge protection module shall be individually connected to the earth bar using the shortest route possible.
- 6.2.10 All surge protection modules shall be DIN rail mountable and use screw terminals for termination of conductors.

- 6.2.11 All SPDs shall comply with the requirements of SANS 61643-1 and shall bear the SABS mark.

6.3 Surge Protection

- 6.3.1 The lightning and switching transients and the regulation of the available 230VAC supplies to the Electronic Assemblies shall be regarded as those relevant to an industrial supply.
- 6.3.2 The Tenderer shall therefore allow for additional surge suppression and voltage stabilisation equipment if this is required to protect his offered equipment and/or to guarantee its correct and reliable operation.
- 6.3.3 Equipment that is connected to signal lines of any type between separate LPZs shall, be surge protected to survive twenty 8/20 μ s current impulses with maximum amplitude of 10 kA when applied in common mode between the signal lines connected together and to the system protective earth.
- 6.3.4 In the case where surge protection equipment is factory fitted into the electronic equipment being offered, but is found to be inadequate to meet this specification, additional external surge protection shall be provided.
- 6.3.5 Equipment which is connected to signal lines of any type between equipment within a common LPZ and for which the signal cable is longer than 30 m, shall be protected as above, except that the maximum amplitude for the common mode test shall be 2 kA and the maximum amplitude for the differential mode test shall be 500 A.
- 6.3.6 Surge protection devices shall be chosen in such a way that the protected circuit shall still function to specification in spite of the introduction of series and/or shunt impedances by the protecting devices.
- 6.3.7 Surge protection shall encompass, but not be limited to the following requirements:
- a) On all analogue/digital input and output circuits - suitable signal surge protection units with appropriate ratings as defined by the relevant SANS 61643.
 - b) On all mains power supply circuits - suitable power supply protection modules as defined by the relevant SANS 61643.
 - c) On all telephone lines - Telkom approved protection network, containing gas arrestors, inductance's, transorb type arrestors and 600 Ω / 600 Ω isolating transformers. Loop and ringing current circuits shall be optically isolated.
 - d) Surge arrestors shall be installed on all phases of the electrical power supply at the input terminals to each equipment cabinet.
 - e) Where external lines have to interface with sensitive electronic equipment, such as computers and associated peripheral equipment, suitable opto-isolators with an isolation level of at least 5 kV shall be installed.
 - f) All co-axial cables shall be provided with in-line surge suppressors.
 - g) It is not anticipated that the stated equipment will, used on their own, necessary provide the required level of protection and the Contractor shall implement additional measures deemed necessary to achieve the required protection level.
 - h) The Engineer may allow the use of alternative types of surge arrestors, provided that equivalent or superior protection levels will be achieved. SABS and/or CSIR test reports to substantiate claims shall be submitted to the Engineer prior to installation for the alternative equipment.
 - i) The connecting cable between electronic units shall have a continuous screen (not bridged) which shall be earthed at both ends.

- 6.3.8 Power supply protection modules shall be used to protect the incoming power supply to the system and for mains supplied stations shall have the following characteristics:
- a) The unit shall be rated to operate at a voltage up to 280V AC/DC.
 - b) The nominal discharge surge current (8/20 μ s-wave) shall be greater or equal to 15 kA.
 - c) The maximum discharge surge current shall be greater or equal to 40 kA.
 - d) The unit shall react in less than 25 ns.
 - e) The unit shall be equipped with a visual indication to indicate a fault within the unit or if it is disconnected from the supply.
 - f) A fault within the unit shall not affect the operation of the power supply.
- 6.3.9 A power supply protection module shall be made up out of two units with the above characteristics the one unit connected between live and neutral and the other between neutral and earth. The earth shall be connected to the lightning protection interface earth bar via the shortest possible route and shall have a conductor cross sectional area of not less than 25 mm².
- 6.3.10 Signal SPD modules shall be of a pluggable design, with the decoupling elements arranged in the plug base element. The decoupling elements shall not be affected by the presence or absence of the protection plug and the removal of the protection plug shall not break the signal circuit.
- 6.3.11 It shall be possible to remove and test the protection unit on site using a portable test set.
- 6.3.12 Signal SPD modules shall be designed for two conductor floating ground circuits and shall offer individual signal line to ground as well as signal line to signal line protection.
- 6.3.13 The protection plug shall have the following basic elements and shall function as follows:
- a) It shall be provided with a gas discharge tube that will absorb the largest part of the energy of an over-voltage impulse.
 - b) It shall be provided with a solid state Zener diode combination which will clamp the output voltage before the gas discharge tube is activated.
 - c) It shall be provided with diodes that will limit the capacitance between lines in order to limit the interference of high frequency signals.
- 6.3.14 The protection unit shall be able to contain over voltages to a maximum of 30 V AC peaks between any of the output terminals and earth or between the two output terminals.
- 6.3.15 Note: The over voltage referred to above, is defined as an over voltage with a rise time of 10 μ s, a peak voltage of 800 V AC, a short circuit peak current of 100 Amp and a voltage down-time linear with a down-time of 50 % of the peak value after 100 μ s. Such an over voltage is generally accepted in the telecommunications industry and represents the maximum energy and typical wave forms that are induced on twisted pair communications lines in the vicinity of lighting.
- 6.3.16 Copies of Type test certificates of the offered protection units shall be submitted to the Engineer for approval.
- 6.3.17 Terminal strip arrangement between RTU and field equipment shall be as follows:
- a) Two separate terminal strips shall be provided, one for digital signals and one for analogue signals. The terminals shall be grouped per field device and secondarily by function (i.e. all inputs together and all outputs together per field device).
 - b) All digital inputs shall be powered by the electronic device's power supply and all digital outputs shall be field powered. All digital signals shall be protected by means of



pluggable signal circuit protection units. The surge protection units shall comply with the relevant SANS 61643.

- c) All analogue inputs will be field powered. All analogue inputs shall be protected by means of pluggable signal circuit protection units. The surge protection units shall comply with the relevant SANS 61643.
- d) In addition to the above, all outgoing and incoming signal lines shall be protected by means of knife disconnect terminal blocks with gas-filled surge arrestors between signal lines.
- e) The pluggable signal protection unit may serve as the terminal block for connecting outgoing cables.
- f) All digital output signals shall be interfaced by means of interposing relays with a single pole change-over contact. The contacts shall be rated for a minimum of 2 A, 230 V at a power factor of 0,8.

6.3.18 The terminal arrangement as detailed above shall have at least 25 % spare space after all incoming cables (including spare cores) have been terminated.

7. SIGNS AND LABELS

7.1 General

- 7.1.1 Safety signs and labels shall be provided wherever necessary in relevant languages so as to unambiguously communicate safety and functional guidance to any person who may operate the Assembly or otherwise come into contact with any part of the electrical or electronic system forming a part of the Assembly, and shall be provided for the specific identification of every component contained within the Assembly.
- 7.1.2 Signs and labels shall be located in such a manner that:
- a) it is obvious as to the nature and location of the hazards or component(s) to which they relate
 - b) when mounted on any enclosure cover or plate, there is no possibility of that cover or plate being interchanged with any similar item on that Assembly or on any other Assembly supplied to the same site
 - c) they are not fixed to easily removable parts (e.g. trunking covers, etc.), unless their purpose is to warn of the consequences of removing a removable part
 - d) they are at all times adjacent to the item to which they refer, and accommodate situations where components could be moved along a DIN mounting rail
 - e) they will not be obscured by any equipment, components, or wiring, etc.
 - f) they are legible and will remain easily read throughout the life of the Assembly
- 7.1.3 Signs and labels shall be securely and permanently fixed using an appropriate number of corrosion resistant, mechanical fixings (double sided adhesive tape will not be accepted). The fixing of labels, safety signs and notices shall not affect the IP rating of the Assembly.
- 7.1.4 Short individually fixed labels covering several items only, shall be used in lieu of long multi-legend labels; e.g. above a row of indicator lamps.
- 7.1.5 Safety signs and labels shall be of such size that the legend thereon is clearly legible from the operating position (or a 3 m distance), and the pictograph and its accompanying text shall be chosen so as to provide the appropriate communication in an explicit and unambiguous manner.
- 7.1.6 Safety signs and labels fixed to the outside of the enclosure shall be manufactured from 1.5 mm thick anti-reflective polycarbonate with the legend reverse screen printed, or alternatively from 3 mm thick bevel-edged clear perspex rear engraved with black characters. Internal labels may be manufactured from a laminated plastic material which shall normally provide a black legend against a white background. Where specifically agreed with the Engineer, internally mounted labels and charts, e.g. for distribution boards, etc., may be of permanently printed plastic, plastic laminated thin card, or thin card protected behind perspex.


7.2 Safety Signs

- 7.2.1 As a minimum, safety signs shall be fitted to removable covers over live connections, and to doors of compartments containing:
- a) incoming supply cable termination points
 - b) functional units incorporating capacitors
 - c) hazardous equipment such as fibre optic laser communications
 - d) equipment located in a 'safe area' but associated with certified apparatus located in a hazardous area; a sign shall also be fitted at the safe area cable termination rail.

- 7.2.2 A safety sign identifying the operating voltage shall be placed in any compartment where there is equipment, components, or wiring, that can be energised at above extra low voltage.
- 7.2.3 Where there is no suitable standard symbol or pictograph, an application specific sign may be produced using simple and appropriate symbols, pictographs, and text, to indicate the hazard in a simple and straight forward manner that is acceptable to the Engineer.
- 7.2.4 Multipurpose signs shall be used where there is a need to communicate multiple hazard messages.

7.3 Labelling

- 7.3.1 The text of every label, excluding individual internal component identification labels, shall be as agreed with the Engineer.
- 7.3.2 Every Assembly shall be provided with a name plate detailing the following:
- a) Manufacturer's name or trademark
 - b) Manufacturer's contact details
 - c) Manufacturer's type designation, serial / identification number
 - d) Date of manufacture
 - e) IP rating
- 7.3.3 An application name shall be prominently displayed on the Assembly, as detailed in the Project Specification.
- 7.3.4 The material used shall be selected having regard to the size and fixing methods of the label and the label shall not warp in service. Labels mounted on the outside of the Assembly shall rectangle in form and be manufactured of either:
- a) Laminated plastic, engraved so as to produce black letters on a white background
 - b) Engraved sandwich board ("Traffolyte", "Darvic" or equal)
 - c) Reverse engraved acrylic material ("Perspex") with filled letters and reverse sprayed
- 7.3.5 For outdoor applications (where specified in the Project Specification) labels shall be brass or aluminium (with letters filled in black), lightly sanded with fine grit paper and clear lacquered.
- 7.3.6 Labels for door mounted components and labels used inside the Assembly shall be to the same standard or may alternatively be printed using an approved, propriety system.
- 7.3.7 Text characters shall be uniform in height, in upper case (except where standard abbreviations of units are used, e.g. kWh, kVA, etc.) and of the following minimum dimensions:
- a) application labels: 8 mm
 - b) compartment designation labels: 6 mm
 - c) information or warning labels: 6 mm
 - d) component identification labels: 3 mm
- 7.3.8 All components shall be clearly labelled. Internal components shall be clearly identified by individual labels to indicate the equipment to which they relate. The component identification labels shall correlate with the Assembly drawings and documentation. If this is not practical due to space restrictions, common labels (e.g. diagrams may be used).

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- 7.3.9 PLC / PCS and Remote Input / Output cards shall be fitted with printed I/O address labels including the TAG numbers where it is practical to do so. Alternatively a plastic laminated label card shall be provided and included in a steel pocket on the inside of the assembly door.



8. INSTALLATION REQUIREMENTS

8.1 Shipping

- 8.1.1 Assemblies shall be shipped in sections to facilitate field handling for transportation and installation. The shipped sections shall be joined together on site to form a complete unit assembly.
- 8.1.2 Preparation for shipment shall protect the Assembly auxiliary devices accessories, etc. against corrosion, breakage or vibration damage during transportation and handling.
- 8.1.3 All parts shall be clearly and permanently marked to facilitate disassembly and packing for transport. Instructions shall be provided for reassembly of sections on site or accompanied by a qualified representative from the Assembly Manufacturer.

8.2 Transportation and installation

- 8.2.1 The Contractor shall be responsible for disassembly, packaging, delivery to site (including loading and offloading) as well as reassembly of all equipment on site.
- 8.2.2 The Contractor shall provide timely information regarding all specialized handling and storage requirements for equipment to be transported and /or handled on the site until finally installed in the operating location.

9. FUNCTIONAL DESIGN

The Engineer will provide the Contractor with the following information, which shall form the basis for the Contractor's design of the Assembly:

9.1 The Project Specification

The Project Specification detailing all project specific requirements.

9.2 Motor and Instrumentation Table

A Motor and Equipment List, and a Instrumentation list providing a list of all externally connected equipment, their function, rating and purpose. It provides the Engineer's estimate of each load's kW rating and the starting method, the process measurement, local visual indication and the requirements for manual, automatic and local control to be implemented.

9.3 I/O List

An I/O List detailing the Engineer's estimate of the input and output signals (analogue and digital) required for motor control, instrumentation and general control purposes.

9.4 Technical Detail Sheets

The Technical Detail Sheets used for Tender purposes, which shall be completed by the Contractor and verified by the Engineer for compliance to the Project Specifications, so as to detail the project and product specific requirements for each Assembly and its constituent functional units before procurement and manufacture.

9.5 Control Philosophy

The Control Philosophy detailing the Engineer's intent for functionality of the plant or works and all automation, control and instrumentation systems.

9.6 Cable Block Diagram

Cable block diagram(s) indicating how the components of the Assembly are to be connected to the motors and instrumentation for the process that must be controlled.

9.7 Assembly general arrangement drawing

A proposed layout providing the Contractor with the Engineer's intent for the layout and relevant sizing of the Assembly.

9.8 Building arrangement and equipment location drawing

A drawing indicating the plant layout, control equipment location and proposed location for the Electronic Assemblies.

9.9 Contractor's Design

The Contractor shall take the Engineer's design and complete it for the equipment offered during tender and approved for construction. Documentation and Drawings to be produced and submitted for approval are described in Section 10 below.

10. TESTING AND COMMISSIONING

10.1 General requirements for testing

- 10.1.1 On completion of manufacture, the Assembly shall be subjected to a factory acceptance test (FAT), comprising the Manufacturer's in-house tests, and the repeat tests witnessed by the Client and the Engineer. All testing shall include both Hardware functional and Software simulation testing.
- 10.1.2 Once the witnessed FAT has been carried out, signed off, and any remedial works have been completed and re-tested, the Assembly is ready for delivery to site. Once erected in position, the Assembly shall be subjected to a witnessed site acceptance test (SAT).
- 10.1.3 Once the SAT has been carried out and signed off, any remedial works shall be completed and re-tested. Plant installation and site cabling will then be carried out by others, and on its completion, witnessed commissioning shall commence.
- 10.1.4 The manufacturer shall allow for each test (apart from in-house tests) to be witnessed by both the Client and the Engineers simultaneously. An individual testing activity shall not be considered to have been completed until results have been recorded, and it has been signed off by the Engineer.
- 10.1.5 The manufacturer shall provide the Client and Engineers with all reasonable facilities, including testing staff and test equipment, to carry out the inspections and tests, and to check the Assembly for compliance with all of the Client's requirements.
- 10.1.6 The manufacturer shall ensure that all testing is carried out in a safe manner and shall be responsible for all measures in accordance with the Occupational Health and Safety Act.
- 10.1.7 During development, software may be electronically verified apart from the Assembly it controls using a simulation / diagnostic package; notwithstanding this, control systems shall be witnessed tested with the software loaded into the programmable devices, and with simulation of the physical I/O devices to equipment such as MCCs.
- 10.1.8 Where the Assembly incorporates equipment requiring special testing facilities or procedures, the manufacturer shall ensure that appropriate resources are available; including where necessary, representatives from the equipment Manufacturer.

10.2 Factory acceptance tests (FATs)

- 10.2.1 The manufacturer shall perform his in-house works tests in accordance with the proposed FAT procedures, and shall satisfy himself as to the accuracy and quality of the manufactured Assembly in accordance with the accepted design. Once the in-house FAT has been carried out, signed off by the manufacturer, and any remedial works have been completed and re-tested, the tests shall be repeated and witnessed by the Client (if required) and the Engineer.
- 10.2.2 When testing the performance of any software, it shall be demonstrated using the hardware intended to be incorporated within the Assembly, and where this is not possible appropriate operator interfaces, programming units, and terminal units, etc. shall be provided. Where it is necessary to demonstrate an interface with a piece of unavailable equipment to be supplied by others, appropriate means to replicate that equipment and simulate the interface shall be provided.
- 10.2.3 The Engineer preserves the right to cancel and postpone tests if he finds that the Contractor has not made reasonably sure that the test will be successful. Any extra costs incurred shall be borne by the Contractor.



10.3 Site acceptance test (SAT)

- 10.3.1 All equipment and every circuit that was altered or disturbed subsequent to the completion of the FAT, or for shipping and site erection, shall be specifically re-tested for integrity and functionality.
- 10.3.2 During the SAT, all cables and terminations shall be subjected to continuity and short circuit tests.
- 10.3.3 The process functionality of each aspect of the control system and its operator interface shall be demonstrated, including the correct operation of all I/O and network links external to the Assembly or not otherwise tested during the FAT.

10.4 Commissioning and other tests

- 10.4.1 The Contractor shall ensure that the Assembly manufacturer provides assistance during the commissioning of the Assembly, whereby the functionality of the Assembly and its control system and software shall be proven. During commissioning the Contractor shall make such adjustments, software modifications, and circuit changes, as are deemed necessary to provide the level of plant functionality and performance specified by the Client. All such changes shall be immediately incorporated into the 'As-Built' documentation and the Operating and Maintenance Manual, by the Contractor.
- 10.4.2 The Contractor shall provide a comprehensive commissioning checklist that shall be used to record the Electronic equipment and Control gear commissioning and tests results, and make provision for formal sign-off of the installation by the Engineer and the Client.

11. DOCUMENTATION AND TRAINING

11.1 General

11.1.1 All Assembly drawings, wiring diagrams, information, and documentation shall be in English, and each item shall be identified with:

- a) the Client's name and contact details
- b) Client's project / scheme / contract reference title and numbers
- c) the Engineer's name and contact details
- d) Engineers reference numbers
- e) Contractor's works / contract / order references

11.1.2 Drawings for acceptance shall be provided on A4 or A3 paper copies as specified.

11.2 Drawings for Approval by the Engineer

11.2.1 The following documentation and drawings shall be submitted to the engineer prior to the procurement or manufacturing of Electronic equipment Assemblies:

- a) General arrangement, typical component mounting plate layouts, and foundation plans.
- b) Wiring schematic diagrams showing all equipment and components incorporated into the Assembly. Known circuitry outside of the Assembly and connected to it, shall be shown on all drawings. Drawings shall be cross-referenced using a grid / line reference system.
- c) Software and configuration documentation; including logic diagrams and function block diagrams. The documentation shall be complete and annotated with purpose, function, duty, cross-references, and descriptions, etc.; sufficient to guide an unfamiliar person through the operation of the software.

11.3 Testing Documentation and Reports

11.3.1 A factory acceptance test (FAT) document shall be provided to the Engineer prior to the witnessed FAT. This documentation shall show the manufacturer's in-house test procedures and results for all items of equipment, components, hardware, and software. The document shall show hardware checks, the software simulation procedures, and their combined functional testing. It shall comprehensively and clearly show the test results of the in-house testing. The subsequent report of the FAT witnessed by the Engineer shall be appended to the contractual documentation.

11.3.2 The Contractor shall provide his own testing report template to document the FAT witnessed by the Engineer. This shall be to the satisfaction of the Engineer.


11.3.3 A site acceptance test (SAT) document shall be produced, which shall detail all tests necessary to demonstrate the functionality of the Assembly following its final erection on site. This shall include details of tests and checks on all circuits disconnected for shipping, together with any equipment, components, wiring, or software altered or incorporated into the Assembly; following the completion of the witnessed FATs.

11.3.4 All drawings, schedules, listings, and other design documentation for acceptance shall be supplied as a comprehensive and integrated package and collated into folders; unless otherwise agreed with the Engineer. Three copies of appropriate documentation shall be submitted on each occasion that agreement is sought.

- 11.3.5 The FAT and SIT shall each have been submitted and agreed with the Engineer, prior to the commencement of final testing and site commissioning.

11.4 Operating and Maintenance Manual

- 11.4.1 One copy of the draft operating and maintenance manual and spare parts list shall be provided at an agreed date; in advance of the date of the start of the final testing and commissioning SATs, for acceptance by the Engineer. Three copies of the final editions shall be provided to the Engineer by an agreed date before successful completion of final testing and commissioning.
- 11.4.2 The Operating and Maintenance Manual shall be bound into a suite of hard-backed ring binders, and shall be provided with an index of all drawings pertinent to the Assembly. The index shall include each drawing's origin, number, issue, status, and the Client's drawing number (where issued by the Engineer).
- 11.4.3 The Operating and Maintenance Manual shall include the following:
- a) All design drawings and documentation relating to the Assembly; as delivered and tested.
 - b) 'As Built' records showing verification against stated design and installation criteria, including a schedule of all the final settings for all user adjustable equipment and components, and copies of all documentation presented and completed during the FATs, the SATs, and any other specified tests on completion.
 - c) Schedules of plant and equipment for each enclosure/ junction box / circuit; including a listing of the applicable standards, manufacturer, settings, type number, re-order code, etc., for each item of equipment and component included within the Assembly.
 - d) Manufacturers' contact details, technical information sheets for all items of equipment and components included within the Assembly. Manufacturers' catalogues may be provided subject to clear identification of the relevant components. All individual manufacturers' equipment / component test certificates and certificates of conformity, shall be included.
 - e) Inspection, testing, and maintenance recommendations, including detailed and specific operation, maintenance, and diagnostic data, and safe isolation information suitable for use by maintenance personnel, shall be provided for all equipment, components, and systems incorporated into the Assembly.
 - f) Schedule of spares provided with the Assembly, including manufacturer, description, part number, order code, and quantity.
 - g) A DVD with all software backups and program code used on all data control devices (i.e. PLC, HMI, SCADA, control panels, industrial networks).
 - h) A schedule of all installed cables, with the following information:
 - i) Tag number
 - ii) From equipment tag number and description
 - iii) To equipment tag number and description
 - iv) Circuit number (DB name, circuit breaker e.g. DB01-CB08)
 - v) Size
 - vi) Installed length; and
 - vii) Function (e.g. "Feeding Submersible pump IW-SP-01")
- 11.4.4 The Operating and Maintenance Manual shall include detailed descriptions for use by the Client, on how the controlled plant and its management systems are intended to operate and be operated; under both manual and automatic control. Clear and detailed descriptions for



each element of the Assembly shall be provided; and shall include system objectives, controlled plant start-up and shut-down procedures, automatic control, manual intervention, primary and secondary control routines, plant selection including duty and standby options, local and remote selections, operational and safety constraints, status information, alarms and control interfaces with SCADA / telemetry systems, fault routines, etc. In other words, the FDS shall be converted to an FD to be inserted in the O&M Manual.

11.4.5 The Operating and Maintenance Manual shall include 'as-installed and tested' information on both the hardware and software for each programmable device incorporated within the Assembly, including:

- a) Overview of system operation in relation to the controlled plant.
- b) System configuration.
- c) Manufacturers' literature on operation, maintenance and testing of hardware and ancillaries, programming instructions, and diagnostics.
- d) Hard copy program; with listings fully documented.
- e) Listing of the final settings of all process dependent variables.
- f) Permanent back-up copies, licensed in the name of the Client, shall be provided for all software, including operating programmes, application programs, and configuration software for all configurable devices.
- g) Any interconnecting leads, protocol conversion modules, connectors, etc. necessary to connect and communicate with each programmable / configurable device to a standard portable Notebook.

11.4.6 The Manual format shall be A4 size with layout suitable for binding in A4 Level Arch type files. Drawings shall be A4 or A3 suitably folded to fit the A4 Lever Arch file.

11.5 Training

11.5.1 Electronic equipment operation and maintenance training shall form part of the overall training programme.

11.5.2 The Contractor shall conduct training courses for designated personnel in the maintenance and operation of the equipment and associated Assemblies.

11.5.3 The Assemblies shall be in a complete working order before training shall commence.

11.5.4 A training schedule, together with the name and background of the person who will perform the training, shall be submitted to the Engineer for approval.

11.5.5 Training and training manuals shall be based on the O&M Manuals.


11.5.6 Training manuals shall be delivered for each trainee with two additional copies delivered for archival at the project site. The manuals shall include an agenda, defined objectives for each course.

11.5.7 Where the Contractor presents portions of the course material by audio visual means, copies of those audio visual presentations shall be delivered to the Employer as part of the printed training manuals.

11.5.8 The Employer reserves the right to videotape the training sessions for later use.

11.5.9 The training shall include operator training and technical/maintenance training.

11.5.10 During the installation phase, a person will be designated by the Employer to be closely involved with the installation and commissioning process. The intention is not to interfere



with the Contractors' installation team, but to do observation in order to obtain the maximum possible information regarding the installation, to enable efficient maintenance to be undertaken by the Employer after final hand-over and expiring of the guarantee period.

11.6 Operations& Maintenance training sessions

- 11.6.1 There shall be training sessions for the operation and maintenance of the Assemblies.
- 11.6.2 The program for the training shall include instruction for at least one day per Assembly (8 hours) instruction on-site.
- 11.6.3 The program shall at a minimum cover the following:
 - a) General system overview
 - b) Functional operation of the system i.e.:
 - i) System start-up and shut-down procedures
 - ii) Equipment operation
 - iii) System access requirements
 - iv) Alarms
 - v) Fault Finding
 - vi) Backup Power Procedure (if applicable)
 - vii) Incident Reporting
 - viii) Maintenance
 - ix) Maintenance Schedule
 - x) Standard Maintenance Procedures
 - xi) Spare Part Lists
- 11.6.4 Upon completion of the course, the operators should be fully proficient in the system operation and have no unanswered questions regarding the system.



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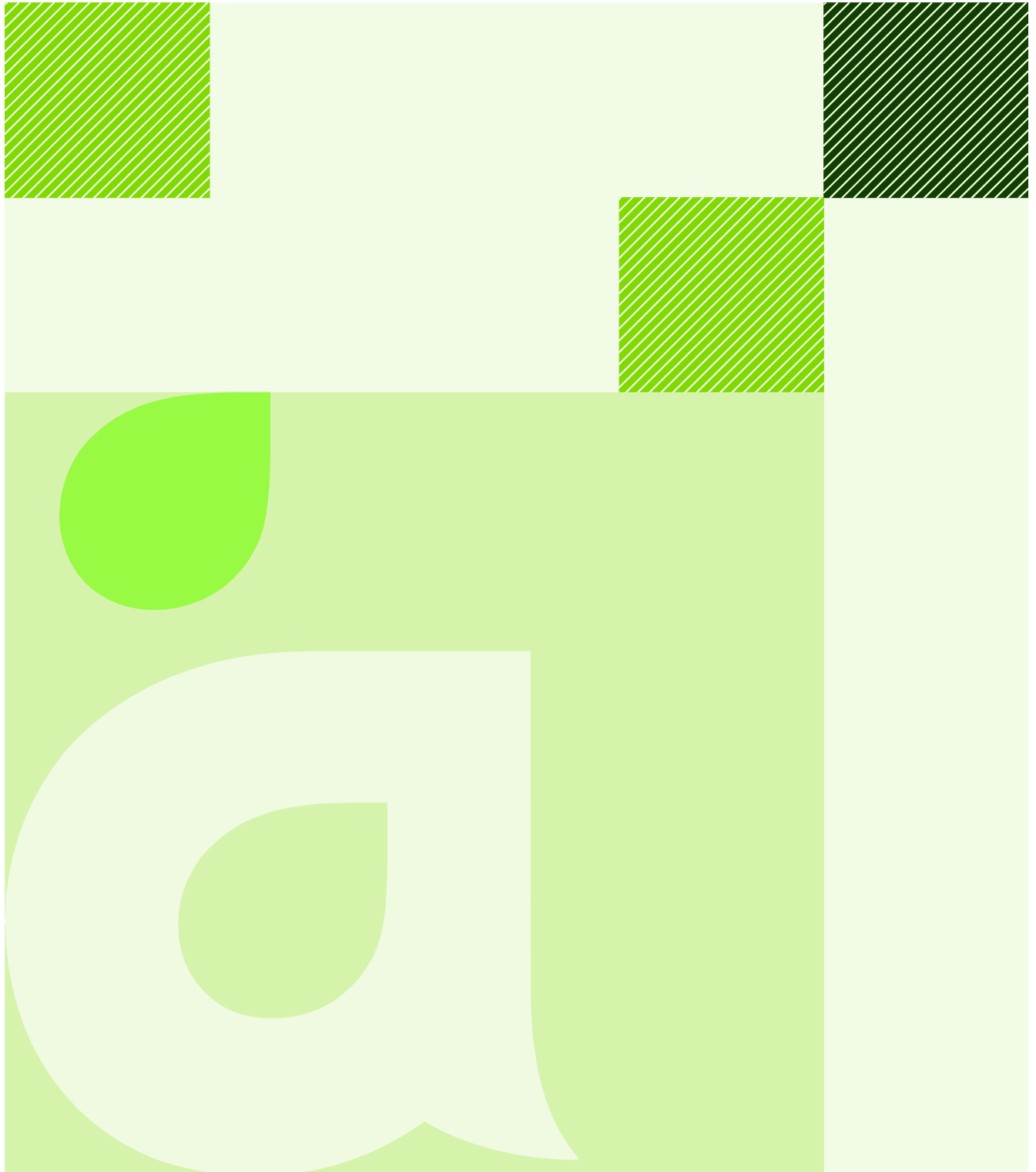
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Engineering Standard

Programmable Logic Controllers (PLC)

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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification defines the requirements for the design, construction, supply, programming, configuration, testing, installation and commissioning of Industrial Process Control equipment such as Programmable Logic Controllers (PLC) and Process Control Systems (PCS) as well as their interfaces to process equipment and instrumentation as well as to operator Visualization systems such as HMI and Supervisory Control and Data Acquisition (SCADA).
- 1.1.2 Where a package plant is offered with integral PLC or PCS this specification shall also apply and the onus is on the tenderer to qualify all deviations (if any) with his offer.

1.2 General Requirements

- 1.2.1 A PLC or PCS shall be provided for each area of the plant or works as listed in the Project Specification and as shown on the Control System Architecture diagram.
- 1.2.2 The PLC or PCS shall be provided complete with all components and peripherals necessary for it to completely control a plant or works and the architecture diagram defines the configuration of the PLC or PCS in terms of localization or centralization, local or remote inputs and Outputs (IO) and data communications interfaces, levels and paths.
- 1.2.3 The PLC or PCS shall be housed in a dedicated control panel or enclosure conforming to the South African National Standard (SANS) for Control Gear as listed in section 2.3 below and the Engineering Standard SPE-II-0001 - "General Electronic Installations".
- 1.2.4 The completed Assembly shall incorporate all components and equipment necessary to reliably achieve the functionality defined in the Project Specification and Control Philosophy.
- 1.2.5 All materials, components, and equipment used in the manufacture of the Assembly shall be new and unused, shall be of current manufacture, and shall be free from any defects or imperfections.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification contains standard amendments and requirements which shall be applied to the referenced statutory and national standards. The project-specific requirements are provided in the Project Specification, which shall be read in conjunction with this Specification.
- 2.1.2 The design, construction, installation, inspection, testing and commissioning of the Assembly shall comply with the Engineering Standard SPE-II-0001 “General Electronic Installations”, all relevant statutory regulations, and the latest editions (current at the time of Tender) of all relevant South African National Standards.
- 2.1.3 The Manufacturer shall follow an approved, auditable quality assurance system covering the design, construction, programming, configuring, inspection and testing of the Assembly.

2.2 Statutory Requirements

- 2.2.1 The Assembly as manufactured, and as installed on site, shall comply with the following:
- a) Occupational Health and Safety Act of 1993
 - b) Manufacturer’s specifications and installation instructions

2.3 Reference Standards

The PLC panel Assembly and all its constituent components, equipment, configuration and programming shall comply with the latest published edition of all relevant national standards, including the following:


Table 1: Reference Standards

Standards	Description
SANS	As listed in the Engineering Standard SPE-II-0001 “General Electronic Installations”
IEC 61131 (Parts 1-8)	Programmable Logic Controllers
IEC 61499-1	Function blocks
ANSI ISA-5.06.01-2007	Functional Requirements Documentation for Control Systems
ANSI ISA-6231-2011	Automation Systems Factory Acceptance Test (FAT), Site Acceptance Test (SAT), and Site Integration Test (SIT)

3. PLC HARDWARE

3.1 General

- 3.1.1 PLC and PCS hardware shall be of a recognised reputable type, approved by the Engineer; from a major international supplier, with a comprehensive and established South African based technical and logistical support operation.
- 3.1.2 The PLC / PCS shall comprise of the following:
- a) Central Processing Unit (CPU)
 - b) dedicated Power Supply Unit (PSU)
 - c) digital and analogue hard-wired input / output (I/O) cards
 - d) remotely connected digital and analogue I/O cards (if and where specified)
 - e) data communications cards and/or ports on the CPU
- 3.1.3 The PLC / PCS shall interface with other devices and systems as follows:
- a) control circuit components, equipment, instrumentation and plant devices
 - b) industrial Ethernet communications to Level 2 visualization and operation equipment
 - c) an open fieldbus communications to Level 0 equipment (if and where specified)
 - d) other process controllers (e.g. variable speed drives, electronic controllers, dedicated equipment control systems or other PLCs)
 - e) remote terminal units (RTUs), and telemetry systems
- 3.1.4 The hardwired I/O and network communication cards, together with the processor and power supply cards, shall all be housed in racks of one or more chassis units. Where chassis units are provided with spare slots for hardware expansion, these shall be protected by proprietary blanking plates. Any spare communications ports shall likewise be protected with dust covers or plugs.
- 3.1.5 The processor memory shall be sufficient to operate the as-installed programme with 20 % spare capacity, and the installed I/O cards shall be sufficient to operate the as-installed programme plus 10 % spare capacity of each I/O type used.
- 3.1.6 Once the program has been entered into the processor memory, it shall remain resident and unaltered, including under power down conditions, until it is deliberately modified by use of a programming unit. The processor shall contain a readily replaceable memory backup battery and indication of battery status.
- 3.1.7 The PLC / PCS shall be programmable using a standard portable notebook computer with suitable software as its programming device. The PLC / PCS shall be provided with all interfacing hardware and software; ready loaded and configured, to permit full access to the programme (including re-programming) via the standard serial communications port of a PC.
- 3.1.8 The processor shall incorporate the following indications as a minimum:
- a) running
 - b) processor watchdog healthy
 - c) and I/O manipulation status
- 3.1.9 The processor watchdog signal shall be configured to raise an alarm upon CPU failure which shall be displayed on the associated HMI / SCADA or telemetry (where applicable).

- 
- 3.1.10 The PLC / PCS CPU shall allow programme changes “on the fly”. In other words, minor changes to the control logic shall not require the CPU to be reset thereby causing the plant or works to be shut-down.
- 3.1.11 The PLC range shall offer various CPU memory, capacity, speed and I/O count sizes to suit the plant or works including “hot-standby”/ redundant CPU possibilities all as called for in the Project Specification.

3.2 PLC I/O


- 3.2.1 I/O cards shall be provided with voltages and signal loop currents (or voltages) as called for the in the Project Specification.
- 3.2.2 The I/O cards shall be keyed or otherwise configured to prevent maloperation if placed in the wrong position in a PLC / PCS rack, and each I/O card shall be capable of being individually removed or replaced without disturbing the wiring to adjacent cards.
- 3.2.3 Each I/O card shall be provided with an individually fused power supply feed, and an I/O card malfunction or power supply failure shall be recognised by the PLC hardware and software and raise an alarm on the CPU, relevant HMI or SCADA.
- 3.2.4 Conventional PLC I/O cards shall be limited to a maximum of 16 channels per card, and each I/O point shall be provided with an I/O status indicator. The use of 32 channel digital input cards will be subject to the card’s cable termination concept and approval of the Engineer.
- 3.2.5 The I/O wiring shall be segregated between input and output cards, and all I/O (including spare I/O) shall be loomed from the PLC card down to knife-edge (‘swinging blade’) disconnect type marshalling terminals from where these shall be marshalled to the field wiring. Where available, proprietary “looms” (connector / termination assemblies) shall be used to connect between the I/O card and the marshalling section.
- 3.2.6 Where it is necessary to maximise plant availability; e.g. with a duty / standby plant configuration, and more than one input card is available, the duty plant inputs shall be assigned to a separate card from the standby plant inputs. The same shall apply to the assignment of outputs to the plant.
- 3.2.7 Where mission critical applications require redundant IO these shall be accommodated by the choice of the PLC and appropriate CPU, and the circuitry shall be equally segregated as described above.

3.3 PLC Remote I/O

- 3.3.1 Where Remote I/O is called for in the Project Specification the I/O cards shall preferable be of the same type and range as those offered for the main PLC with centralised I/O.
- 3.3.2 Data communications from the PLC / PCS to Remote I/O shall be via a dedicated data communications medium and protocol specifically design for Remote I/O and the Data Communications medium from the PLC to HMI, SCADA or Field instrumentation may not be used for this purpose.

3.4 PLC I/O circuits

- 3.4.1 Digital input circuits, whether hard-wired to conventional I/O or connected via remote I/O, shall consist of volt-free contacts from control circuit components, equipment, and plant devices. These circuits shall be energised from the PLC end, and shall be “fail safe” in design, i.e. contacts shall open on PLC failure or alarm conditions and normal plant status conditions shall provide normally open contacts.

- 
- 3.4.2 Digital outputs shall be provided with integral changeover relay contact suitably rated for the required switching duty, and shall be provided with suppression devices when switching DC loads. Alternatively, transistor output cards may be used in which case suitably rated interposing relays shall be included for each digital output in the Assembly.
 - 3.4.3 Analogue input and output cards be capable of a minimum analogue to digital conversion resolution of 12 bits and shall include open circuit and short circuit monitoring.
 - 3.4.4 Analogue inputs shall be powered either from the field instrument they connect to (where the instrument is separately powered with 230 V AC or 24 V DC), OR from a fused 24 V DC power supply at the PLC side where the instrument is loop powered. Each instrument loop circuit shall be designed for a loop impedance not exceeding 250 ohms.
 - 3.4.5 Analogue outputs shall be powered from a fused 24 V DC supply via the analogue output card, and shall be able to drive into an impedance of up to 750 ohms. Analogue outputs shall provide a direct connection to the load (i.e. the whole primary loop).
 - 3.4.6 Digital Inputs and Outputs shall be galvanically isolated in groups on no more than eight.
 - 3.4.7 Analog Inputs and Outputs shall be individually galvanically isolated.

4. PLC SOFTWARE

4.1 General

- 4.1.1 PLC application software shall be written to meet the requirements of the plant or works Control Philosophy and the PLC processor shall be capable of being programmed using ladder logic, control system flow chart or statement list in accordance with SANS 61131-3. The software shall be laid out in a modular manner and structured in program and function blocks, such that similar tasks are of a similar structure and functionality to facilitate efficiency and ease of programming and maintenance.
- 4.1.2 Standard software Function Blocks shall be built up using the Client's standard suite of function (when available), or the PLC manufacturer's recommended standard Function Blocks.
- 4.1.3 Each line of code shall be fully documented and annotated, using mnemonics directly related to the associated item of plant. Function blocks shall be provided with descriptors e.g. analogue handling block, PID block, motor start block, etc. All data areas used shall be documented and a full memory map provided.
- 4.1.4 The PLC application software and operating data shall be held in appropriate memory locations; secured against power failure, and shall be provided with the facility for password protection against unauthorised access.
- 4.1.5 A sudden interruption of the power supply to the PLC shall result in the programme failing to a safe condition, and the PLC system shall not require manual attendance following a supply failure or restoration. The software control routines shall provide safe power-on and power-off sequences to ensure that the process is in a safe and controlled condition at all times.
- 4.1.6 Where a PLC forms part of a networked plant control system, it shall have a standalone operating capability such that in the event of a network failure it shall be able to continue monitoring and controlling its associated plant; using any set-points and parameters available prior to any network failure, including the ability for operators to change duties, monitor alarms, etc. via any associated local operator interface such as an HMI as called for in the Project Specification.
- 4.1.7 All software necessary to programme, operate, or maintain any equipment or component within the Assembly, including any network connectivity software, shall be provided, and shall be licensed in the Client's name.

4.2 PLC software structure

The PLC application software controlling the plant shall be structured so as to provide, as a minimum requirement, the software routines for each key functional area as detailed in the following clauses:

4.2.1 Plant initiation

This key functional area shall contain routines developed to control plant start-up and restart, plant reset, and phased plant starting, after a power supply re-energisation; including a return to the control mode selected prior to powering down. Plant trips, when reset by the operator, shall reinstate normal automatic operation without the need for further operator intervention.

4.2.2 Plant automatic control

This key functional area shall contain all software necessary to provide automatic control of the plant process(es) and shall include alarm generation and exception handling, together with the starting-up and scheduling of any associated standby plant.

4.2.3 Plant shutdown

This key functional area shall contain routines developed to control plant shutdown, including under operational, power failure, and unplanned / emergency conditions.

4.2.4 Operator and remote interface(s)

This key functional area shall contain all software necessary to provide interfaces to the local HMI, and to SCADA or telemetry (where required). All digital points to / from the HMI, to / from the SCADA system, or to the telemetry system, shall be held within separate integer registers or memory areas, and all analogue points to / from the HMI, to / from the SCADA system, or to the telemetry system, shall be held within separate floating point registers or memory areas.

4.2.5 Interlocks

The PLC / PCS programming shall provide for two types of interlocks namely process and safety interlocks.

a) Process Interlocks:

- i) These are dictated by the physical flow of material through the plant and are typically programmed between motor, valve, actuator and controller software blocks.
- ii) Equipment being prevented from start-up by a process interlock shall clearly indicate this condition on the SCADA system.

b) Safety Interlocks:

- i) These are typically hardwired into the motor, valve or actuators control circuit, latched and reset in the MCC whilst monitored by the PLC and shall indicate as faults on the HMI or SCADA system.

4.3 PLC software control routines

4.3.1 The development of the PLC application software shall include as a minimum, the routines detailed in the following clauses.

4.3.2 For all plant items, the selection of automatic control via the auto-available input signal shall be recognised by the PLC and displayed at the associated HMI, SCADA (and where appropriate, at a remote telemetry SCADA terminal). When an item of plant is selected for hand control, facilities for the rescheduling of any standby plant shall be provided.

4.3.3 Direct operator control via the PLC of each plant item (where that plant item is selected for automatic control) shall be provided from the associated HMI (and where appropriate, at a remote SCADA terminal). The selection of direct control shall leave the plant item state unchanged until a new control command is issued, at which time the rescheduling of any standby plant item shall take place.

4.3.4 Where duty / standby (or assist) plant is provided, the software control regime shall provide scheduling of these plant items through rotation of the duty / standby (or assist) functions. The duty rotation shall be dependent either upon the hours run for that item of plant selected for duty, or upon the issue of a manual duty rotate command. The required duty hours

(between zero and 999) shall be entered by the operator at the associated HMI (or where appropriate, at a remote SCADA terminal). An entered value of zero duty hours shall inhibit the duty function within the associated plant item's duty rotation cycle. For those areas of plant where an apportioned wear pattern is required, an operator warning message shall be issued if the duty cycle hours entered for each item does not provide an uneven wear pattern. Where the operation of plant items is determined by upper and lower process limits, the automatic changeover of duty status shall be delayed until an appropriate point within the operating cycle.

4.4 PLC monitoring software

- 4.4.1 Monitoring software shall be provided to confirm the running of plant items in response to any start command, and shall use separately configurable time delays for each item of plant. If an item of plant fails to start within its configured time, the item of plant shall be deemed to have failed and an alarm shall be generated. The monitoring software shall also provide the accumulated run hours for all motor driven and proprietary items of plant.
- 4.4.2 When an item of plant fails, the control system shall automatically reschedule any standby plant item in place of the duty plant, and execute the appropriate shut-down sequence for the failed plant item. The standby plant item shall continue to operate in place of the failed duty plant item, until the plant item failure condition has been reset by the operator. Once the plant item failure condition has been cleared by the operator, the restored duty plant item shall operate and the standby plant item shall return to its standby status.
- 4.4.3 Monitoring software shall be provided to confirm the position of all valve(s) and penstock(s) in response to any open or close request, and shall use separately configurable time delays for each valve or penstock. If a valve or penstock fails to achieve the requested position, within its configured time, the valve or penstock shall be deemed to have failed and an alarm shall be generated.
- 4.4.4 Monitoring software shall be provided for the associated HMI, SCADA (and where appropriate, at a remote telemetry SCADA terminal), to generate operator message prompts where there is a need to manually exercise control over items of plant which remain in a static operating position or dormant state for extended periods of time. Where applicable, such plant will be identified in the Project Specification and / or Control Philosophy.
- 4.4.5 The PLC application software shall check all analogue input signals for validity. An analogue input signal shall be converted to a digital value at the I/O card, i.e. the current loop signal shall be converted to 0 - 4095 bits. The PLC software shall periodically check for a conversion which indicates under-range or over-range. If either of these two states is set, the software shall initiate an 'out of range' alarm.
- 4.4.6 In order to prevent the operator being presented with excessive spurious alarm messages, the PLC application software shall include routines, that on the initiation of a specific event alarm, shall prevent cascade alarms from being raised i.e. a 'mains failure' alarm will mask the 'not available' alarms from individual motor starters, valves, etc.
- 4.4.7 The PLC application software shall generate totalized quantities for individual items of equipment and instrumentation, whereby a pulsed digital signal shall be received and a set amount added to a totalizer register. The set amount used to increment the totalizer shall be adjustable and stored in a register. The totalizer shall be capable of the range 0 to 999999, and the totalizer shall automatically rolling over to zero when the maximum figure has been reached. The totalizer figures shall be displayed on the associated HMI display, SCADA (and where appropriate, at a remote telemetry SCADA terminal).



4.5 Functional Specification

- 4.5.1 Prior to programming the PLC or PCS, the Contractor shall provide the Engineer with a Control System Functional Design Specification describing how the Plant or Works Control Philosophy will be implemented in the Control System Software (PLC/ PCS).
- 4.5.2 The Functional Specification shall include at least the following:
- a) Control System Overview
 - b) Final Approved plant or works Control Philosophy
 - c) Equipment, Motor and Instrumentation Lists
 - d) PLC IO lists
 - e) List of Interlock signals
 - f) List of Alarms
 - g) List of all PID control Loops
 - h) List of all Sequence and / or Duty/ Standby control
 - i) Detail description of PLC configuration and software building blocks (Function Blocks)
 - j) Function Block Parameters tables
- 4.5.3 The Functional Specification shall be issued to the Engineer for approval.
- 4.5.4 On completion of the contract the Functional Specification shall be converted into a Control System Functional Description and incorporated into the Operations and Maintenance Manuals.



5. INSTALLATION REQUIREMENTS

- 5.1.1 The PLC / PCS shall be installed in a dedicated enclosure conforming to the Engineering Standard SPE-II-0001 “General Electronic Installations”.
- 5.1.2 A separate Assembly shall be provided for each plant or works control area as called for in the Project Specification.
- 5.1.3 Each Assembly shall be physically located in the plant or works electrical load center(s) together with the associated Low Voltage Motor Control Center(s) (MCCs) OR in a dedicated centralized control room with remote IO at the MCC; all as called for in the Project Specification.
- 5.1.4 The installation, termination, earthing and lightning/ surge protection of the PLC/ PCS enclosure (and all associated components) shall conform to the requirements of the Engineering Standard SPE-II-0001 “General Electronic Installations”.



6. TESTING AND COMMISSIONING

The Controller Assembly(ies) shall be tested and commissioned as described in the Engineering Standard SPE-II-0001 “General Electronic Installations” with specific attention to the following:

- a) During development, software shall be electronically verified apart from the process it controls using a simulation / diagnostic package.
- b) The control systems shall be tested with the software loaded into the programmable devices, and with simulation of the physical I/O devices to equipment such as MCCs and Field Instrumentation and the Operator interface HMI and / or SCADA.



7. DOCUMENTATION AND TRAINING

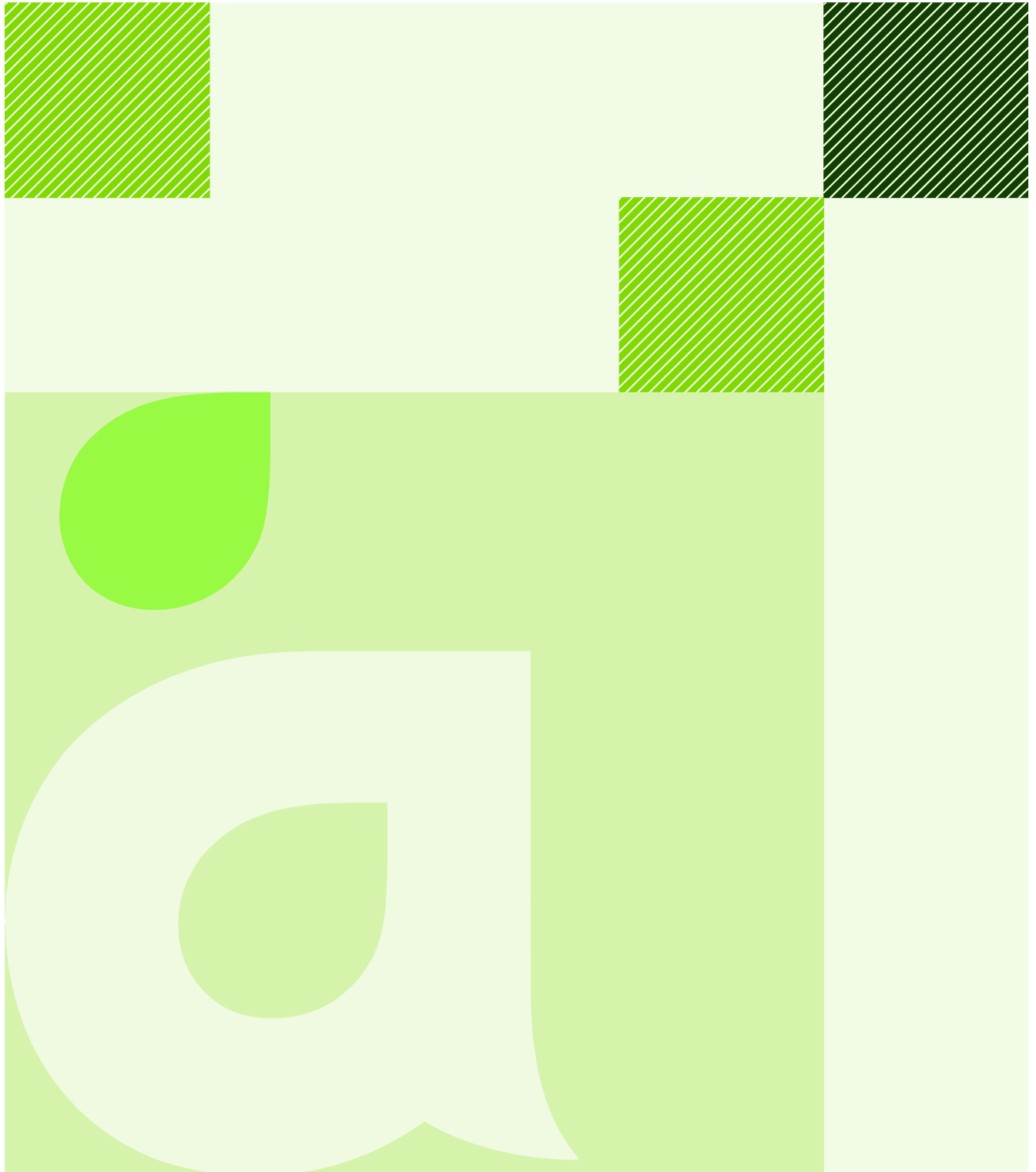
Comprehensive documentation, training and operations & maintenance manuals shall be provided for each PLC / PCS Assembly provided for the plant or works under this contract, all as described in the Engineering Specification SPE-II-0001 "General Electronic Installations".



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1. SCOPE

1.1 Application

- 1.1.1 This Standard Specification defines the requirements for the design, construction, installation, inspection, testing and commissioning of Industrial Information and Communication Networks.

1.2 Installation Performance Requirements

- 1.2.1 The network installation shall be suitable for its intended duty with respect to data rate.
- 1.2.2 The network installation shall be suitable for the environmental conditions, particularly with respect to corrosion resistance and ingress protection.
- 1.2.3 The installation shall be suitable for its intended location, particularly with respect to the mechanical properties and impact strength of the components' parts.
- 1.2.4 The installation, including its circuit arrangements, shall satisfy the operational and functional requirements of the Employer and be readily and easily maintained throughout its operating life.

2. STANDARDS

2.1 Associated Documentation

- 2.1.1 This Specification identifies the Employer's standard modifications and requirements, which shall be applied to the statutory and recognised standards. The detailed specification of the project or site specific requirements will be found in the Particular Specification and its accompanying Data Sheets, which shall be read in conjunction with this Specification.
- 2.1.2 The design, construction, installation, inspection, testing and commissioning of the Installation shall comply with all relevant Statutory Regulations, and the latest editions (current at the time of Tender) of all relevant South African National Standards.
- 2.1.3 Any items not specifically detailed in this Specification, which are necessary to provide a safe and fully operational working system, shall be deemed to be included.
- 2.1.4 The Manufacturer shall operate an auditable quality assurance procedure covering the design, construction, inspection and testing of the industrial information and communications network.

2.2 Regulations, Specifications and Standards

- 2.2.1 The design, construction, inspection and testing of the Industrial Information and Communications Networks shall comply with all relevant Statutory Regulations and Directives including:
- a) Occupational Health and Safety Act (Act 85 of 1993);
 - b) Manufacturer's specifications and installation instructions
- and the latest editions (current at the time of Tender) of all relevant SANS, British Standards and International Standards, including:

Table 1: Reference Standards

SANS Number	Description
SANS 10142-1	Wiring Code
SANS 60793	Optical Fibres
SANS 60794	Optical Fibre Cables
SANS 11801	Information technology - Generic cabling for customer premises
SANS 61000	Electromagnetic compatibility (EMC)
BS 6701	Telecommunications equipment and telecommunications cabling - Specification for installation, operation and maintenance
BS EN 50174-1	Information technology - Cabling installation
IEC 61158-2	Industrial Communication Networks - Field bus specifications - Part 2: Physical layer specification and service definition

- 2.2.2 The installation shall also comply with:
- a) This Specification including all Data Sheets; and
 - b) Any documentation issued by, or on behalf of, the Employer in respect of the Installation.
- 2.2.3 The Contractor shall operate an approved, auditable quality assurance procedure covering the design, construction, and inspection and testing of the Installation.

3. NETWORK INSTALLATION

3.1 All Networks

3.1.1 General

- a) The Contractor shall be competent at Industrial Network installation. Competence shall be achieved by:
 - i) Installation personnel having attended an approved Modbus/optical fibre network installer's course and passed all relevant examinations; or
 - ii) Installation personnel having a proven track record of successful Modbus/optical fibre network installation on other similar projects; or
 - iii) Other equivalent route approved by the Employer.
- b) Installation shall comply with IEC 11801 and BS 7601.
- c) The design of the Network shall comply with IEC 61158-2 - Industrial communication networks - Fieldbus specifications – Part 2: Physical layer specification and service definition; and IEC 50174-1 - Information technology: Cabling installation.
- d) The network shall be standardised as far as possible to Modbus. Communication should either be via Modbus TCP or serial Modbus communication.
- e) All cabling and equipment shall be labelled.

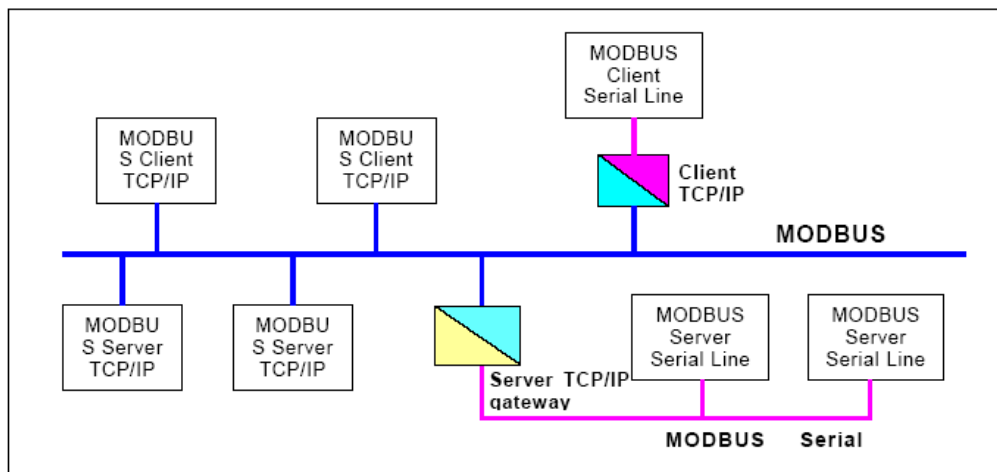


Figure 1: A typical Modbus Industrial Network (Source www.modbus.org)

4. MODBUS TCP/IP

4.1 General

- 4.1.1 All components in the Industrial network capable of communicating over Modbus TCP shall be connected to the communication network.
- 4.1.2 Components shall be configured in the most appropriate topology for the application.
- 4.1.3 The installation of the network shall be according to the Ethernet communication standards IEEE 802.3.

4.2 Copper Cabling Component Selection

4.2.1 General

All components shall be suitable for their intended duty, particularly with respect to the following:

- a) The degree of ingress protection (IP rating) required.
- b) The environmental conditions (particularly corrosion resistance).
- c) The data rate/bandwidth should not be less than 10Mbps/s.

4.2.2 Copper Cabling

- a) The cable shall comprise a shielded (STP) or unshielded (UTP), twisted pair cable of Cat 5 or Cat 6 as specified in the Particular Specification and Technical Data Sheets.
- b) Physical layer shall be according to one of the following standards 10BASE-T, 100BASE-TX, or 1000BASE-T depending on the bit rate that is required.
- c) Data cables shall be grey.
- d) Copper cable runs may not exceed 90 meters, to allow for patch leads and fly leads.
- e) If there is a significant likelihood of the cable being subjected to high mechanical stresses or attack by vermin during service and it is not practical to protect it by guards or other equivalent means, then the cable shall be armoured.

4.2.3 Connectors (If Required)

- a) Connectors shall be suitable for the type of cable being installed and the type of device socket into which the cable will be connected.
- b) All floor outlets must be of the RJ45 type.
- c) The connector design shall ensure simple and effective connection of the cable cores and screen.
- d) All connector pins and sockets shall, as a minimum, be flash gold plated.

4.3 Copper Cabling Installation

4.3.1 Cable Routing and Installation

- a) The cable installation shall be according to BS EN 50174-1.
- b) Cable routing/installation shall comply with the relevant parts of Engineering Standard SPE-II-0001 – “General Electronic Installations”.
- c) If network cables are routed underground, they shall be installed in ducts and not directly buried in the ground.

- d) All bending of cables shall be in accordance with the manufacturer requirements.

4.3.2 Attaching Connectors to Cables

- a) Connectors shall be attached to cables strictly in accordance with the connector manufacturer's instructions.

4.4 Fibre Optic Cabling Component Selection

4.4.1 Network Design

The usual approach in designing an optical fibre network shall be as follows:

- a) Determination of the transmission path length.
- b) Selection of the most appropriate type of optical fibre cable according to the required transmission path length.
- c) Selection of suitable devices for the chosen optical fibre cable.
- d) Selection of suitable connectors for the chosen devices.

4.4.2 Optic Fibre Cables

- a) Cables shall comply with SANS 60793 and SANS 60794.
- b) The fibre optic cable shall be single mode or multimode as specified in the Particular Specification and Technical Data Sheets. Unless otherwise stated multimode fibre shall be used for path lengths up to 550 m.
- c) Unless otherwise stated in the Particular Specifications or Technical Data Sheets 2N redundancy (2 times the amount of cores that is needed) shall apply.
- d) Physical layer for multimode fibre shall be according to one of the following standards 100BASE-FX, 1000BASE-SX, 10GBASE-SR, 10GBASE-LX4 depending on the bit rate that is required.
- e) If there is a significant likelihood of the cable being subjected to high mechanical stresses or attack by vermin during service and it is not practical to protect the cable by guards or other equivalent means, then the cable shall be armoured.

4.4.3 Fibre Optic Cable Splicing


- a) All splicing shall be of the fusion splice type and no mechanical splices are to be used
- b) A maximum splice insertion loss of 0.3 dB per splice shall be allowed.
- c) All fusion splices shall be done in splice enclosures of the correct type and size suitable for the environment and specific installation and shall have a warning label affixed unto the outside cover.
- d) All splice joints shall have a splice protector over them.
- e) All splice enclosures shall have a record sheet/label inside denoting the planning and use of the fibres according to colour coding and/or numbering. Furthermore, this shall be dated and labelled according to areas and/or signals in use.

4.4.4 Fibre Connectors

- a) Connectors shall be suitable for the type of cable being installed and the type of device socket into which the cable will be connected.

4.5 Fibre Optic Installation

4.5.1 Cable Routing and Installation

- 
- a) Cable routing/installation shall comply with the relevant parts Engineering Standard SPE-II-0001 – “General Electronic Installations”.
 - b) Connector attached to pre-assembled cables shall be fitted with dust-protection caps (or equivalent protective measures) to prevent dirt/debris ingress during cable routing and installation.

4.5.2 Cable Routing and Installation

- a) Connectors shall be attached to cables strictly in accordance with the connector manufacturer's instructions.
- b) Due to the potentially hazardous nature of fine glass fibres, all waste generated during assembly of glass optical fibre cables shall be removed from site and disposed of appropriately.

5. MODBUS OVER SERIAL LINE

5.1 General

- 5.1.1 Modbus over serial line shall be used where Modbus TCP communication is not viable, e.g. from PLC to Modbus enabled field instruments.
- 5.1.2 RS232 or RS 485 shall be used as physical interface.
- 5.1.3 RTU mode shall be the transmission mode.
- 5.1.4 The baud rate shall not be less than 19.2 kbs.
- 5.1.5 RS 232 interface should only be used for short length (typically less than 20 m) point to point interconnection.
- 5.1.6 For RS 485 either 2-wire or 4-wire configuration may be used.
- 5.1.7 Devices shall be connected to the trunk cable using spur cables and junction boxes.

5.2 RS 485

5.2.1 Topology

- a) 32 Devices are allowed on any RS 485-Modbus system without repeater. In practice the number of devices shall be limited to 25 to allow for:
 - i) Spare capacity for future installations
 - ii) The connection of diagnostic/programming equipment to the segment
- b) The RS 485-Modbus configuration without repeater shall have one trunk cable, along which devices are connected directly (daisy chaining), or by short spur cables.
- c) The length of the trunk cable shall be limited. The maximum length depends on the baud rate, the type of cable (Gauge, Capacitance or Characteristic Impedance), the number of loads on the daisy chain, and the network configuration (2-wire or 4-wire). The Contractor shall be able to submit prove that the length of the cable installed is indeed less than the maximum length for the specific installation.
- d) The spur cables shall be short, never more than 20 m. If a multi-port tap is used with n spur lines, each one spur line shall have a maximum length of 40 m divided by n.

5.2.2 Earthing Arrangements

- a) The Common circuit (Signal and optional Power Supply Common) must be connected directly to protective ground, preferably at one point only for the entire bus. Generally, this point shall be on the master device or on its tap.

5.3 Component Selection

5.3.1 Terminations

- a) A reflection in a transmission line is the result of an impedance discontinuity that a travelling wave sees as it propagates down the line. To minimise reflections from the end of the RS485-cable, a line termination shall be placed near each end of the trunk cable. The termination shall comprise a capacitor and resistor in series connected between the cable cores.

- b) It is important that the line be terminated at both ends since the propagation is bi-directional. More than two terminators shall not be placed.
- c) Line terminations should not be placed on spur cables.
- d) In RS232 interconnections, no termination should be wired.

5.3.2 Cables

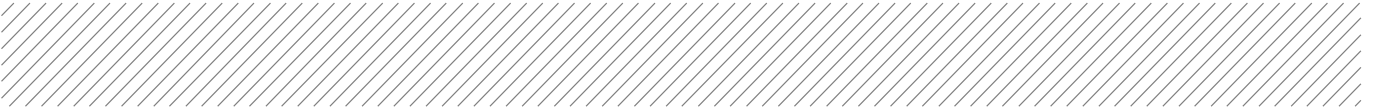
- a) The cable shall be a screened, twisted pair cable complying with IEC 61158-2.
- b) A Modbus over Serial Line Cable must be shielded. At one end of each cable its shield must be connected to protective earth. If a connector is used at this end, the shell of the connector shall be connected to the shield of the cable.
- c) An RS485-Modbus configuration shall use a balanced pair and a third wire (for the ground). In addition to that a second balanced pair shall be used in a 4 wire-Modbus system.
- d) If there is a significant likelihood of the cable being subjected to high mechanical stresses or attack by vermin during service and it is not practical to protect the cable by guards or other equivalent means, then the cable shall be armoured.
- e) For a RS485-Modbus the wire gauge must be chosen sufficiently wide to permit the maximum length (1000 m). AWG 24 is sufficient for Modbus Data.
- f) Category 5 cables maybe used for RS485-Modbus, to a maximum length of 600 m.
- g) For the balanced pairs used in an RS485-system, a characteristic impedance with a value higher than 100 Ohms shall be used, especially for 19.2 kbs and higher baud rates.

5.3.3 Junction Boxes

- a) Each spur cable shall be connected to the trunk cable via a junction box (a single junction box may be used for connecting one or more spur cables to the trunk cable).
- b) Junction boxes shall be suitable for their intended duty, particularly with respect to the following:
 - i) Ingress protection (IP) rating;
 - ii) Corrosion resistance; and
 - iii) Impact strength.
- c) The method of connecting the spur cable to the junction box shall be via an M 12 connection.
- d) Junction boxes shall ensure uninterrupted bus operation when exchanging devices or extending spur cables.
- e) Junction boxes shall incorporate a termination resistor that may be switched in or out, as required.

5.3.4 Connectors

- a) Connectors shall be suitable for the type of cable being installed and the type of device socket into which the cable will be connected.
- b) The following connectors shall be used:
 - i) RJ45
 - ii) 9-pin Sub-D connector

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- c) The connector design shall be ensure simple and effective connection of the cable cores and screen.
 - d) All connector pins and sockets shall, as minimum, be flash gold plated.

6. EARTHING AND EQUIPOTENTIAL BONDING

6.1 General

- 6.1.1 The network shall be provided with an effective earthing and equipotential bonding system to:
- a) Ensure effective earthing of cable screens/devices, thus ensuring that electrostatic interference is diverted to earth as opposed to causing pickup in the device electronic circuits; and
 - b) Ensure that the earth potential is the same at all points across the network to prevent earth currents flowing through the cable screens.
- 6.1.2 To prevent electrical currents passing along the screens of cables connecting devices installed in parts of the network subject to different earth potentials (e.g. between different buildings etc.) one of the following measures shall be adopted:
- a) The devices shall be connected together with an optical fibre cable; or
 - b) A potential equalisation cable shall be run alongside the network cable to equalise the earth potentials (refer to later Section, Potential Equalisation Cable).

6.2 Earthing of Cable Screens

- 6.2.1 At the Device
- a) The cable screen shall be earthed at both ends of the cable i.e. at every device.
 - b) If connectors are used to attach the cable to its associated devices, the screen shall be earthed via the connector when the connector is plugged into the device (assuming the device is earthed). If connectors are not used, (i.e. for devices that require direct cable connection), the device shall incorporate suitable features/facilities for earthing the cable screen.
- 6.2.2 At the Assembly Entry
- a) To prevent any outside interference (picked up by the cable) being transmitted into an Assembly, the cable screen shall be earthed at the point of entry of the cable into the Assembly.
 - b) To facilitate this connection, the Assembly shall be provided with an earthing rail at the Assembly entry behind the cable strain relief.
 - c) The large surface area connection between the cable screen and the earthing rail shall be achieved with an approved, proprietary screen connection clamp.
 - d) The following points shall be observed when making the earthing connection:
 - i) To avoid unnecessary weakening of the cable around the earthing connection, the outer cable sheath/insulation shall only be removed where required for earthing purposes;
 - ii) The earthing connection shall not be used as a strain relief since this may reduce its effectiveness and cause the cable screen to be damaged (an exception would be when using parts that are specifically designed for this purpose);
 - iii) To protect the weakened cable from damage, it shall be securely fixed to the Assembly either side of the earthing connection;

- iv) The size of the screen connection clamp shall be accurately matched to the cable diameter to ensure that the screen is securely connected to the clamp without pinching;
- v) The connection between the screen and the earthing system shall only be made using the braided screen. Many fieldbus cables feature a foil screen and this shall not be used to achieve the earthing connection;
- vi) The earthing rail may be attached to galvanized or plated surfaces but not to painted surfaces; and
- vii) All metallic components comprising the earthing connection shall be inherently corrosion resistant or otherwise be protected against corrosion to ensure that the earthing connection remains effective for the asset life of the network.

6.3 Earthing of Devices

6.3.1 Devices shall be earthed in accordance with the device manufacturer's instructions.

6.3.2 This shall normally be achieved via either:

- a) The device earth terminal; and/or
- b) The device mounting arrangement (i.e. bracket, rails or screws etc.).
- c) Earthing connections shall be made using copper cables with an appropriate cross sectional area ($> 2.5 \text{ mm}^2$).

6.4 Potential Equalisation Cable (If Required/Provided)

6.4.1 If there are large variations in earth potential at different points within the installation, connecting both ends of the cable screen to earth can lead to current passing along the cable screen; this current is to be avoided since it can lead to interference pickup.

6.4.2 This situation can occur if:

- a) The network cable covers a large area or extends over a long distance;
- b) Power is supplied to different sites from different sources (i.e. sub stations); and/or
- c) Heavy electrical currents are present (e.g. arc furnaces, power stations etc.).

6.4.3 If there are large variations in earth potential at different points across the installation, a potential equalisation cable may be installed to equalise the earth potentials.

6.4.4 To ensure that the cable is effective at earthing high frequency signals, it shall be finely stranded with a large surface area.

6.4.5 The potential equalisation cable shall be laid parallel to and as close as possible to the network cable to minimise the area enclosed between the two cables. The cable may also be used as to provide protection against the effects of a lightning strike.

6.4.6 The potential equalisation cable can carry significant current and shall be sized in accordance with IEC 60364-5-54.

7. DRAWINGS AND DOCUMENTATION

7.1 General

- 7.1.1 Drawings and Documentation of the Industrial Network shall be required for the Control System Functional Specification as described in Engineering Standard SPE-II-0001 – “General Electronic Installations”.
- 7.1.2 After completion of the network installation and before final commission, the Contractor shall provide the Employer with a set of ‘as-built’ network installation drawings and cable schedules, which shall form part of the Operation and Maintenance Manual.
- 7.1.3 Any changes made during Commissioning shall be incorporated into these Manuals.
- 7.1.4 The Drawings and Documentation that shall form part of the Operation and Maintenance Manuals is described below.

7.2 Drawings

- 7.2.1 Drawings shall be to a standard scale and be sufficiently detailed to serve the purposes of recording the Industrial Network installation.
- 7.2.2 Drawings shall, as a minimum, show the following details:
 - a) The general arrangement of all devices (i.e. masters, slaves, active terminators etc.) connected to the network;
 - b) The routes of all network cables with associated cable references;
 - c) Buried network cables and associated cable marker posts;
 - d) Cable ducts, draw pits and pre-cast service trenches, etc. utilised by the network;
 - e) All splice enclosure locations;
 - f) Earthing/bonding conductor routes and connections; and
 - g) The boundaries of any areas that have been classified as hazardous areas.

7.3 Cable Schedules

- 7.3.1 Comprehensive cable schedules shall be provided, detailing all cables, including earth cables, which are installed.
- 7.3.2 As a minimum, the following information shall be provided, per circuit, on each cable schedule:
 - a) Cable reference number;
 - b) Cable source and destination (including the compartment reference number in the cases of cables which terminate at multi-compartment motor control centres, etc.);
 - c) Route length; and
 - d) Method of installation.

8. TESTING AND COMMISSIONING

8.1 Installation Verification

8.1.1 General

Before the start of any network installation activities, the Contractor shall provide the Employer with details of any deviations from the proposed network design for approval.

8.2 Network Testing

8.2.1 Pre-Commissioning Testing of Installation and Wiring


- a) Installation and wiring testing shall include the following activities:
 - i) Visual checking of the cable specification, layout (spurs), routing, segregation, support and lack of damage;
 - ii) Connector and termination wiring, termination check, correct use of in/out cable entry;
 - iii) Wiring check for shorts, open circuits, crossed wire etc. (including screening);
 - iv) Bonding and earthing, potential equalisation;
 - v) Addressing check (duplicate addressing can be difficult to diagnose); and
 - vi) Segment cable length check (can be done with analyser and scope) and device count check.
- b) Following testing, the Contractor shall provide the Employer with a certificate of validation stating that the network is free of connection problems (i.e. crossed wires, screening faults etc.) and is correctly earthed etc. This certificate shall be accompanied by a schedule of all tests conducted from the PLC to each device including the reported cable length for each test. The final test shall be performed at the furthest device on the network to give an estimate of the overall network cable length. The schedule shall include a specific measurement of the length of any spurs incorporated at device connections, with a summation of the total spur length provided at the end of the schedule. In addition, a marked up and commented drawing indicating any changes to the original design shall be provided.

8.2.2 Commissioning Testing (Health Checking)

- a) The network shall be subjected to Commissioning Testing (Health Checking) to check for interference and reflections etc. using an analyser and oscilloscope.
- b) On a powered network, the Contractor shall undertake a diagnostic test to validate the active network as being able to operate at the design baud rate using an approved test device.
- c) The certificate of validation shall be endorsed to state that the network can operate at the design speed, and that any reflections will not be detrimental to the operation of the network for the asset life.

8.2.3 Optical Fibre Testing

- a) All terminated links shall be tested using a Power Meter and Light Source (PMLS) Tests, an optical time-domain reflectometer (OTDR) may only be used as an additional test. The tests shall include the full set of tests required to confirm performance to ISO/IEC 14763-3 specification.

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- b) The tester shall have a certification of calibration current to within the tester manufacturer's specification.
 - c) Multimode fibre shall be tested using the 3-jumper method. Testing shall be undertaken in both directions at 850 nm and 1300 nm.
 - d) Single mode fibre shall be tested using the 3-jumper method. Testing shall be undertaken in both directions at 1310 nm and 1500 nm.
 - e) Cable length shall be verified either by using an OTDR or it may be directly determined from the cable metre marking.

8.2.4 Dark fibre

- a) All un-terminated links (dark fibre) shall be tested using an OTDR to verify fibre integrity and length. Connection to the OTDR may be made using a reusable mechanical splice incorporating index-matching gel or by OTDR accessories such as bare-fibre adapters.
- b) Cable length shall be verified using either an OTDR or may be determined from the cable metre marking.
- c) OTDR test may be undertaken in one direction and at one wavelength only confirming fibre integrity.



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