Engineering Standard

SAES-P-119 30 March 2005

Onshore Substations

Saudi Aramco DeskTop Standards

Table of Contents

1 Scope..... 2
2 Conflicts and Deviations..... 2
3 References..... 2
4 Definitions..... 4
5 General..... 5
6 Substation Buildings..... 7
7 Substation Yard..... 10
8 Power System SCADA Requirements..... 16

Attachment 1 – SCADA Electrical Equipment Definitions..... 26
Attachment 2 – SCADA Wiring & Connection for the Transformer Tap Changer Position, Voltage, Watt, & Var..... 27
Attachment 3 – SCADA Wiring & Connection for Circuit Breaker Closing & Tripping Circuit..... 28
Attachment 4 – SCADA Wiring & Connection for the Transformer Tap Changer Control Circuit..... 29

1 Scope

This standard prescribes the mandatory requirements for the design and installation of onshore power substations. This document may not be attached to nor made a part of purchase orders.

2 Conflicts and Deviations

2.1 If there are any conflicts between this Standard and associated project or engineering documents, this standard shall take precedence. The exception is if an approved Waiver Request Form SA 6409-ENG has been included with the purchasing documents.

2.2 Any conflicts between this Standard and other Mandatory Saudi Aramco Engineering Requirements (MSAERs*) or referenced industry standards shall be identified to the Company or Buyer Representative who will request the Manager, Consulting Services Department of Saudi Aramco, Dhahran to resolve the conflict.

* *Examples of MSAERs are Saudi Aramco Materials System Specifications (SAMSSs), Engineering Standards (SAESs) and Standard Drawings (SASDs).*

2.3 Direct all requests to deviate from this Standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward Waiver Request Form SA 6409-ENG to the Manager, Consulting Services Department of Saudi Aramco, Dhahran requesting his approval.

2.4 The designation "Commentary" is used to label a sub-paragraph that contains comments that are explanatory or advisory. These comments are not mandatory, except to the extent that they explain mandatory requirements contained in this SAES.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-B-014	*Safety Requirements for Plant and Operations Support Buildings*
SAES-B-055	*Plant Layout*
SAES-K-001	*Heat Ventilating and Air Conditioning*
SAES-K-002	*Air Conditioning Systems for Essential Operating Facilities*
SAES-M-006	*Saudi Aramco Security and General Purpose Fencing*
SAES-M-100	*Saudi Aramco Building Code*
SAES-O-100	*General Requirements Safety and Security*
SAES-O-109	*Minimum Standards for Buildings Housing Sensitive or Vital Equipment*
SAES-P-101	*Regulated Vendors List for Electrical Equipment*
SAES-P-103	*Direct Current and UPS Systems*
SAES-P-111	*Grounding*
SAES-P-116	*Switchgear and Control Equipment*
SAES-P-123	*Lighting*
SAES-P-126	*Power Monitoring System*
SAES-S-020	*Industrial Drainage and Sewers*

Saudi Aramco Materials System Specifications

14-SAMSS-536	*Pad-Mounted Three-Phase Distribution Transformers*
16-SAMSS-502	*Metal-Enclosed Low-Voltage Switchgear Assemblies*
16-SAMSS-503	*Indoor Controlgear – Low Voltage*
16-SAMSS-504	*Indoor Metal-Clad Switchgear 1 to 38 kV*
16-SAMSS-506	*Indoor Controlgear - High Voltage*
16-SAMSS-510	*Manually Operated Pad Mounted SF_6 Switchgear: 1 kV to 36 kV*
16-SAMSS-514	*Control and Protective Relay Panel – Indoor*
34-SAMSS-815	*Annuciators*

Saudi Aramco Standard Drawing

AB-036319	*Standard Sign: Danger High Voltage*

Saudi Aramco Form and Data Sheet

SA 6409-ENG	*Request for Waiver of Saudi Aramco Engineering Requirement*

3.2 Industry Codes and Standards

American National Standards Institute

ANSI C2	*National Electrical Safety Code*
ANSI/NFPA 70	*National Electrical Code*
ANSI/IEEE 979	*IEEE Guide for Substation Fire Protection*
ANSI/IEEE 980	*IEEE Guide for Containment and Control of Oil Spills in Substations*
IEEE C37.1 - 1994	*IEEE Standard Definition, Specification, and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control*
IEEE 605 - 1998	*IEEE Guide for Design of Substation Rigid-Bus Structures*
IEEE 998 - 1998	*IEEE Guide for Direct Lighting Stroke Shielding of Substations*

4 Definitions

ACC: Accumulator

Controlgear: is equipment manufactured to either 16-SAMSS-506 (Indoor Controlgear - High Voltage) or 16-SAMSS-503 (Indoor Controlgear-Low Voltage).

IFC: Interface Cabinet

PDD: Power Distribution Department

RTU: Remote Terminal Unit.

SCADA: Supervisory Control and Data Acquisition. See IEEE C37.1 - 1994.

Secondary-Selective: A **switchgear** assembly consisting of two buses connected with a single **bus tie breaker**. Each bus has one breaker to receive incoming power. (i.e.,

power flow into and between the two busses is controlled with three breakers). Also, referred to as "double-ended" switchgear.

SOE: Sequence of Events (time-tagged status points)

SEC: Saudi Electrical Company

Switchgear: Is equipment manufactured to either 16-SAMSS-502 (Metal-Enclosed Low-Voltage Switchgear Assemblies) or 16-SAMSS-504 (Indoor Metal-Clad Switchgear 1 to 38 kV).

5 General

5.1 Terms in **bold** font are defined within Section 4.

5.2 Saudi Aramco defines a substation as any assemblage of electrical equipment which includes a power transformer rated 751 kVA and larger or **switchgear** rated 1 kV and higher. *This standard does not apply to* pad-mounted **switchgear** manufactured to 16-SAMSS-510 or pad-mounted distribution transformers manufactured to 14-SAMSS-536.

Commentary Note 5.2:

See SAES-P-116 for guidance on equipment that is located in substation buildings.

5.3 Substations shall be in accordance with the ANSI/NFPA 70 (National Electric Code) and ANSI C2 (National Electrical Safety Code) as supplemented by this Standard.

5.4 Location of substation and substation equipment shall comply with SAES-B-055. Substations shall be located in non-classified areas. However, substations may be elevated on a plinth located above a 600 mm high extended Class I, Division 2 or Zone 2 hazardous area. Equipment located in the substation yard may be located in the extended 600 mm high Class I, Division 2 or Zone 2 hazardous area if all enclosures containing arcing, sparking, or heat producing devices are located above the hazardous area (i.e., the bottom of the enclosure is above 600 mm).

5.5 Each substation building shall be provided with one or more annunciator panels meeting the requirements of 34-SAMSS-815 for indication of urgent and non-urgent alarms. A common trouble alarm shall be extended to a manned facility. When output contacts are provided in the transformer, circuit breaker, or **switchgear** equipment for the following alarms, individual indication shall be provided on the annunciator panel.

a) Loss of circuit breaker tripping supply

b) Loss of **switchgear** protection supply

c) Loss of circuit breaker charging motor supply

d) Loss of circuit breaker SF_6 gas pressure

e) Low circuit breaker operating air pressure

f) Power transformer combustible gas present

g) Power transformer pressure relief valve operated

h) Power transformer Buchholz relay operated

i) Power transformer high winding temperature

j) Power transformer loss of reference potential on Automatic Voltage Regulator (AVR)

k) Power transformer loss of cooling fan supply voltage

l) Power transformer low transformer oil

m) Power transformer high oil temperature

n) Power transformer low tap changer oil level

o) Power transformer loss of tap changer motor operating supply

p) Power transformer tap changer failure

q) Alarm points from **Switchgear** and **Controlgear**

Commentary Notes 5.5:

Alarms are equipment specific. Most substations will not have all of these alarms. Some substations will require alarms that are not listed.

For SCADA alarms, refer to Section 8 of this document.

5.6 Tap changer, automatic voltage regulator, protection and circuit breaker control panels shall be located inside the substation building when associated equipment is located in an outdoor transformer yard or switchyard (e.g., transformer with an automatic tap changer or outdoor circuit breaker).

5.7 HV Control and Protection panels shall be supplied either by the circuit breaker manufacturer or an approved HV Control and Protection panel manufacturer, in conformance with SAES-P-101 and 16-SAMSS-514. Control and Protection panels shall be arranged as follows for each: Line protection and metering, Bus Bar Protection, Feeder Protection and metering, Circuit Breaker Bay Control including Breaker failure protection, and Automatic voltage regulation. The panels shall be of simplex type having front door access with relays surface

mounted on the door. Circuit breaker control and indication functions shall be arranged on the circuit breaker control panels to represent the substation configuration (e.g., Breaker and half, inverted PI, etc.) and be interconnected by a mimic line diagram indelibly represented on the surface of the panel with a maximum of one substation bay per panel

5.8 Substations that will be maintained and operated by **SEC** may be built to **SEC** requirements.

5.9 Substations shall have a grounding system meeting the requirements of SAES-P-111.

5.10 The bay spacing of transformers and the location of the incoming circuit breakers on switchgear lineups shall be positioned to minimize metal enclosed bus or cable bus length and/or eliminate bends. Preferably the incomer circuit breakers shall be located at the ends of the switchgear lineup. All unavoidable bends in cable bus or metal enclosed bus shall be inside the substation building.

5.11 High voltage disconnect switches shall be manually operated double break, center rotation type located at the tubular bus level.

5.12 High voltage equipment not covered by a Saudi ARAMCO material specification shall not be applied unless technically reviewed by CSD. The review shall as a minimum include design/type test certification, equipment instruction and maintenance manuals, and a user list with contact information. This includes but is not limited to the following:

- Lightning arrestors
- External free standing outdoor current transformers
- Coupling capacitance voltage transformers (CCVT's)
- Neutral grounding resistors
- Disconnect switches
- Grounding switches
- Post insulators
- Hybrid switchgear

6 Substation Buildings

6.1 Substation buildings shall be constructed in accordance with SAES-M-100 and where required SAES-B-014.

Commentary Note 6.1:

SAES-B-014 has specific requirements for buildings in near or associated with plants and may require a Building Risk Assessment Study that may affect the construction of the building.

6.2 Passageways shall be unobstructed and shall provide a minimum 2.3 m headroom.

6.3 Cable trays shall be installed parallel and at right angles to building walls. Sufficient space shall be provided around cable trays to permit adequate access for installation and maintenance of cables. The elevation of the bottom of the lowest interior cable tray shall be a minimum of 2.67 m above the main substation floor. A minimum of 460 mm shall be maintained between the top of any cable tray and the ceiling or roof joist (whichever is closer). All cable trays shall have a minimum of 300 mm clear space above the tray.

6.4 Conductors shall enter the building through walls only.

Exception 6.4:

Existing substation buildings that were designed based upon floor entry of cables and conduits.

6.5 Conductors shall enter the equipment from the top.

Exception 6.5:

Existing substation buildings that were designed based upon floor entry of cables and conduits.

6.6 Exterior illumination shall consist of HID high pressure sodium type fixtures controlled by a photo cell. A Hand-Off-Automatic (HOA) selector switch shall be provided in accordance with SAES-P-123 requirements for exterior illumination controls.

6.7 All interior substation lighting shall be fed from different power supplies (i.e., fed from two different low voltage switchgear bus).

Commentary Note 6.7:

This requirement can be implemented by equally distributing the substation lights between two low voltage panelboards or feeding all substation lights from one panelboard fed from two different power supplies through manual Transfer Switch (TS).

6.8 Emergency interior illumination shall be provided by one of the following:

6.8.1 Self-contained, battery-powered emergency lighting units, with integral charger, which are automatically energized upon loss of 120 VAC power.

6.8.2 Uninterruptible Power Supply (UPS) system located in the substation.

6.9 Duplex, 3-wire, 20 A, 120 VAC (NEMA 5-20R) convenience outlets shall be provided throughout the substation building. A minimum of one outlet shall be provided for each 6 m of wall space at 1 m above the floor. A minimum of two outlets per substation shall be provided.

6.10 Each substation building shall be provided with a redundant air-conditioning system in accordance with SAES-K-001 and SAES-K-002. The indoor temperature in battery rooms shall meet the requirements of SAES-K-002. For normally occupied substations, the office facility or other occupied area shall meet the indoor temperature requirements of SAES-K-001 for offices. Temperature requirements for unattended substations are also specified in SAES-K-001.

Commentary Note 6.10:

Unattended substations require a design maximum temperature of 35°C, however, the HVAC for the battery room is required to maintain 25°C.

6.11 Substation roof drainage shall not be to the transformer yard side of the substation building.

6.12 If a substation is to be constructed over existing pipelines or cable, it shall be elevated. The minimum clearance under elevated substations shall be 1.8 m. The space below elevated substations shall be freely ventilated on at least three sides. The ground below the building shall be at or above finished grade. The space under the building shall be enclosed with grillwork suitable for the environmental conditions and a lockable gate to permit access only to authorized personnel. The grillwork and the gate shall be connected to the substation grounding system. The space under the building shall not drain to the transformer yard side of the substation building. The space under the building adjacent to the transformer yard shall have a solid wall (fire-rating the same as the building wall) that separates the space from the transformer yard.

6.13 The concrete floor in front of **switchgear** shall be flush with the roller level of lower breaker carriage rack and have a smooth surface to facilitate removal and rolling of breaker.

6.14 Leveling steel beams or channels shall be provided for all **switchgear** and **controlgear**. Design and installation of these channels shall be in accordance with the recommendations of the **switchgear** and **controlgear** manufacturer.

Alternatively the floor shall be Horizontal in both planes with a maximum surface height variation less than 5mm per 3 meters. The floor shall also be surface hardened for rolling stock.

6.15 Substation buildings shall have a minimum 2 hour fire rating and be constructed in accordance with SAES-M-100 and where required SAES-O-100 and SAES-O-109 standards.

6.16 A battery room and battery handling facilities shall be provided for stationary batteries in accordance with SAES-P-103.

6.17 Circuit breaker testing facilities and operating tools shall be provided and installed in the substation in accordance with SAES-P-116.

6.18 Substation buildings with single-ended **switchgear** shall be designed to accommodate future **double-ending**.

Commentary Note 6.18:

*Since providing for future **double-ending** will require additional floor space, this should be addressed in the design basis or project proposal documents.*

6.19 Substation buildings shall have telephone and data communications. This shall include connection to the plant local area network and serial or other appropriate communications links between the substation and control room required for data transfer. SAES-P-126 mandates a dedicated (stand lone) Ethernet network for the power monitoring system.

6.20 Substation buildings shall have provisions for mounting and protecting as-built key one-line diagrams for ready reference of operating personnel.

6.21 Substation buildings shall have smoke detection systems per SAES-B-014.

7 Substation Yard

7.1 For pad-mounted on-shore installations, outdoor electrical equipment shall be placed on concrete pad elevated a minimum of 100 mm above neutral grade. Unless greater clearances are specified by the NEC, a minimum of 2 meters working clearance is required on all sides. Additionally, 3 meters clearance is required on equipment having doors or panels which can be exposed to live parts.

7.2 Transformers containing more than 7570 liter of insulated oil shall not be located closer than 6.1 meters (Figure 1) to any building regardless of building rating and a minimum of 15.25 meters (Figure 2) from none fire rated buildings as specified in ANSI/IEEE 979.

7.3 Transformers containing more than 7570 liter of insulated oil shall be separated by 9.1 meters minimum of clear space as specified in ANSI/IEEE 979 (Figure 2), unless separated by a minimum one-hour fire rated barrier then the required space is per paragraph 7.1.

7.4 The height of a fire barrier shall not be less than 300 mm above the height of transformer tank, conservator (if applicable), transformer bushing, and pressure relief vents, etc (Figure 1). The fire barrier shall extend at least 600 mm horizontal beyond the line of sight between all points on adjacent transformers (Figure 1). The height of the fire barrier shall be enough to break the line-of-sight from any point on the top of the transformer and adjacent transformer as specified in ANSI/IEEE 979.

7.5 Oil containment and/or oil drainage systems shall be provided for oil filled equipment containing more than 2,500 liters of oil. Oil containment and drainage systems shall meet the general requirements of ANSI/IEEE 980 and the specific requirements of SAES-S-020. Oil containment is not normally required for pad mount transformers up to 1500 kVA. For power transformers up to 2.5 MVA oil containment shall be in the form of toe walls of sufficient height and area to contain twice the oil volume of the transformer. For power transformers 2.5 MVA and above oil containment shall be in the form of a concrete pit constructed around the transformer foundation. The pit shall be equipped with a steel grating covered with crushed rock to a minimum thickness of 300 mm for fire quenching. The crushed rock shall be a minimum sieve size of 25 mm uniformly graded. The steel grading mesh size shall be less than 25 mm^2. A removable section, with a steel lid not covered with crushed rock, shall be provided in a corner of the steel grating to allow access for cleaning. A sump shall be provided at a corner of the pit for collection of rain water or oil. The sump shall have means of drainage either by suitable connection to sewers or other means of fluid removal.

Commentary Note 7.5:

Oil containment shall be designed to accommodate environmental conditions. Pits completely filled with crushed rock shall not be used since they must be made extremely large to contain the oil volume plus the crushed rock and they cannot be easily cleaned of wind blown sand accumulation.

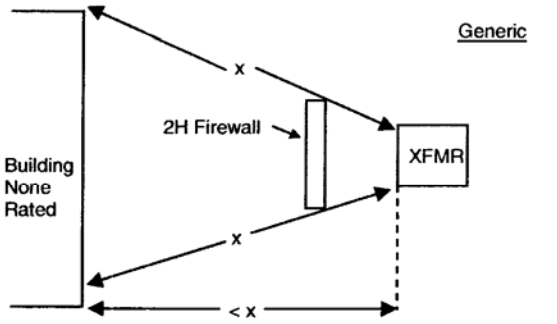
7.6 Transformer Neutral Ground Resister (NGR) shall be located in the substation yard. NGR shall not be mounted on a transformer

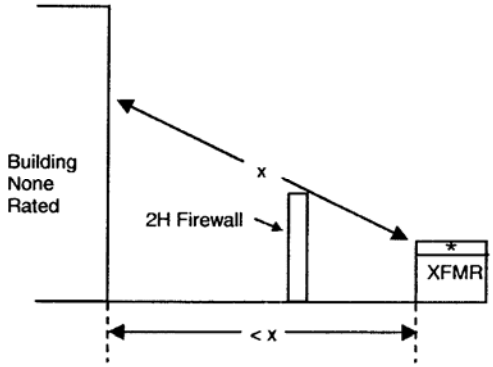
SPACING REQUIRMENT

PLAN VIEW

SECTION VIEW

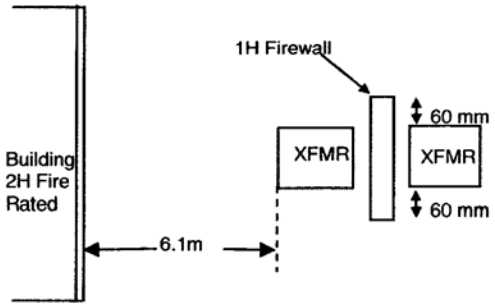
Generic



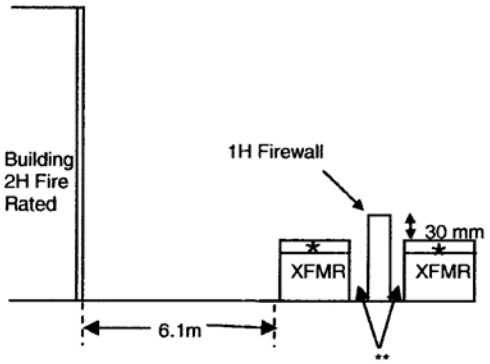


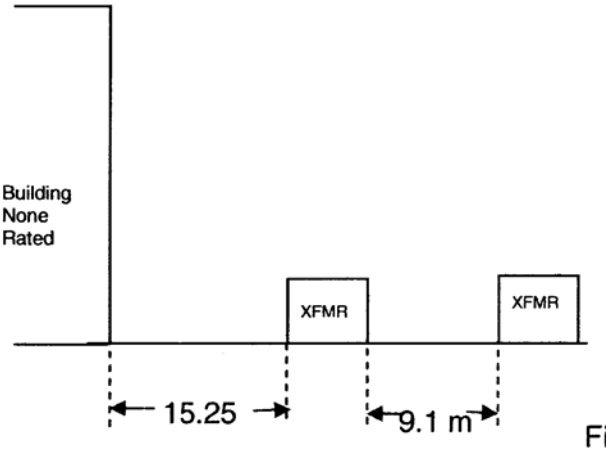
PLAN VIEW

SECTION VIEW

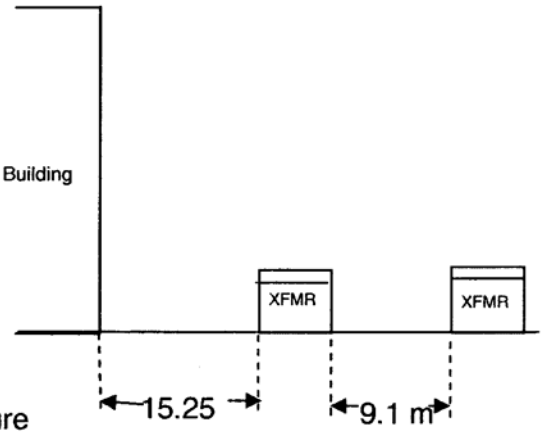


Figure





Figure



Notes:
X = Minimum separation distance
*= Above the highest point bushings or Conservator tank
**= typical, paragraph 7.1 requirements

7.7 The substation yard shall be completely covered with an asphalt-aggregate mixture.

Commentary Note 7.7:

The high surface resistivity of an asphalt-aggregate mixture under both wet and dry conditions reduces the number of ground grid conductors required to obtain safe step and touch potentials during ground faults.

7.8 Substation yards shall be enclosed. Fences shall be constructed in accordance with the requirements of SAES-M-006. Warning signs shall be in accordance with Saudi Aramco Standard Drawing AB-036319 and shall be posted on the fence at intervals not to exceed 6 m.

7.9 Equipment located in the substation yard shall not be accessible from the roof of the substation building.

7.10 Sufficient 120 VAC, 20 A, single-phase, three-wire grounded receptacles shall be installed so that a receptacle is located within 6 m of each power circuit breaker and each power transformer. Receptacles shall be attached to structural or equipment support columns. Exterior 120 VAC receptacles shall be protected with a ground fault circuit interrupter (GFCI).

7.11 The outdoor high voltage substation and switchyard (69 kV and above) shall be in accordance with the following:

7.11.1 Outdoor Rigid Bus design shall be in accordance with IEEE Guide for Design of Substation Rigid-Bus Structures, IEEE 605 - 1998.

7.11.2 Unless otherwise specified, bus conductors shall be manufactured from Schedule 40/80 seamless aluminum alloy tubing, temper 6063-T6.

7.11.3 Vertical bus deflection under maximum loading conditions, including the weight of vibration damping measures, shall be limited to 0.5% of span length.

7.11.4 Maximum horizontal span length between bus supports shall be 10 meters.

7.11.5 Vibration damping shall be accomplished by inserting stranded bare conductor inside the rigid bus tubing. The stranded conductor shall be of the same material as the tubing to prevent corrosion.

7.11.6 The rigid bus shall be joined by welding. Bolted joints in the tubular bus are not acceptable.

7.11.7 Connections to the tubular bus shall either be welded or via welded pads providing standard NEMA bolt pattern.

7.11.8 Flexible joints shall be provided to control expansion on bus runs longer than 30 meters.

7.11.9 Welded grounding lugs shall be provided on the bus tubing for the attachment of safety grounds. The ground lugs shall be located on the rigid bus on both sides of disconnect switches and circuit breakers.

7.11.10 Connection from rigid bus to circuit breakers shall be via stranded cable jumpers with compression fittings and NEMA bolt pattern for both the bus and circuit breaker connections.

7.11.11 Rigid bus supports shall be constructed from steel I-beam, steel pipe or square section steel tubing.

7.11.13 Composite bus support post type insulators shall be used comprising silicone rubber compound external insulation over a solid fiberglass core with ANSI/IEEE/NEMA bolt patterns.

7.11.14 Electrical clearances shall be in accordance with ANSI C2 (NESC).

7.11.15 Shielding, against direct lightning strike, shall be designed in accordance with IEEE 998 - 1998.

7.11.16 The outdoor HV substation and switchyard dimensions shall be as indicated in Table 1 & Figure 1.

Table 1 – Outdoor HV Substation and Switchyard Dimensions (in meters)

Voltage	A	B	C	D	E	F	G	H
69KV	4.3	4.0	2.8	1.6	4.9	1.3	15.3	4.6
115KV	7.4	4.0	3.1	4.9	4.9	2.5	15.3	4.6
230KV	9.1	6.2	5.0	4.9	6	3.1	19	4.6

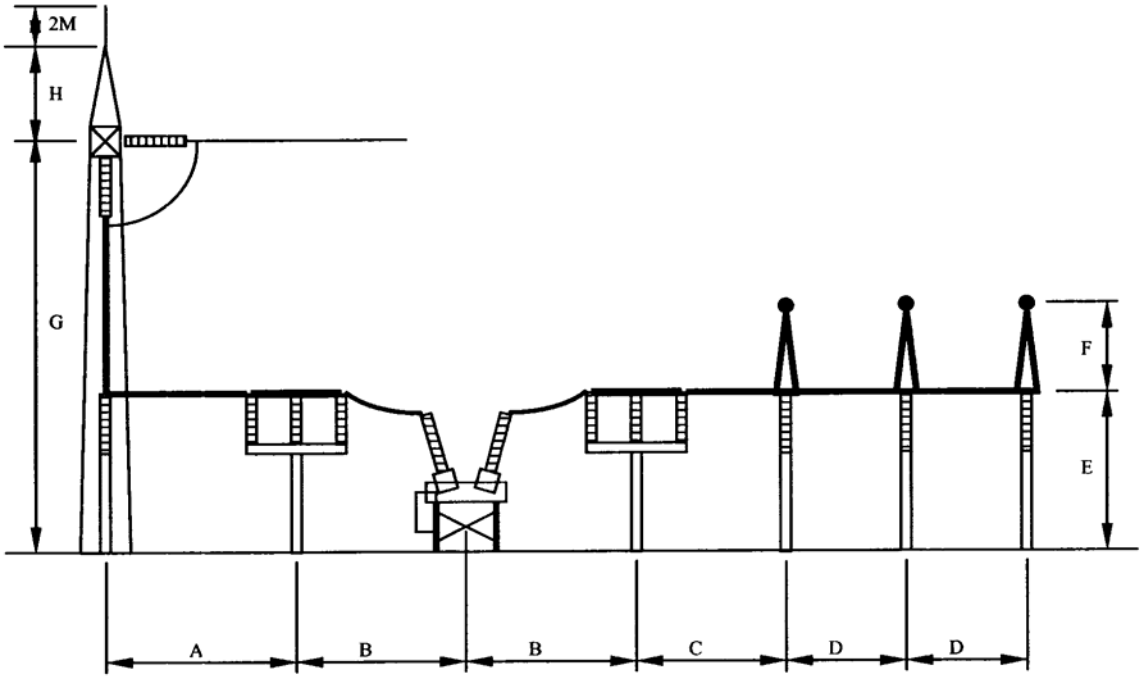


Figure 1: Outdoor Substation Dimension

7.12 Exposed equipment insulators, except for surge arresters, shall have a minimum leakage distance of 40 mm per kV line-to-line of the nominal system voltage.

7.13 Surge arresters shall be of the composite insulation type with silicone rubber compound external insulation over a hermetically sealed fiberglass core. The voltage rating of arresters used in substations shall be as indicated in Table 2. On systems with nominal operating voltages of 13.8 kV and above, surge arresters shall be installed in substations at the following locations: (1) At interface points between overhead lines, open bus and underground lines; (2) On power transformer terminals which are connected to overhead lines or open bus. Unless otherwise specified, surge arresters are not required for transformer connections to insulated cable or gas insulated **switchgear**. Where required, intermediate class arresters shall be used to protect transformers rated 10 MVA and below and station class arresters shall be used to protect transformers rated greater than 10 MVA.

Commentary Note 7.13:

Ratings in the table are based on solidly grounded systems which is the Saudi Aramco standard for these nominal system voltages. Ungrounded or resistance grounded systems require higher arrester ratings. MCOV is "Maximum Continuous Operating Voltage".

Table 2 – Required Arrester Ratings vs. System Voltages

Nominal System Voltage (kV)	Maximum System Voltage Rating (kV)	Duty Cycle Rating (kV rms)	MCOV (kV rms)
34.5	38	30	24.4
69	76	60	48.0
115	127	108	84.0
230	253	192	152.0

7.14 Surge arrester grounding terminals shall be connected, with minimum bends, directly to the ground bus or grid or, in the case of surge arresters mounted on transformers, directly to the grounding pad provided on the transformer.

8 Power System SCADA Requirements

8.1 **SCADA RTU** shall be installed in substations meeting the following criteria:

Power receiving substations: any substation that will interface with **SEC** network or independent power generation supplies.

Transmission and sub transmission substations: any substation that is supplied by 69 kV or above transmission lines.

8.2 **SCADA RTU** point requirements shall be implemented as per the following Tables.

Table 3 – SCADA Standard Point List

Equipment	Status	SOE	ACC	ANALOGE	CONTROL
Line (from Line PTs)	Primary Relay (94P)Set Supply Lost 2nry Relay (94S)Set Supply Lost	Primary Relay Set (94P) operated 2nry Relay Set (94S) operated		K. Volts M. Watts M. VARS Frequency	
Line Incoming Breaker (from bus PTs)	Trip coil monitoring relay 74TC1 & TC2 Closing coil monitoring relay 74CC. Local / Remote Urgent Alarm Non-Urg. Alarm 86 Dc supply lost (7486)	Open/ Closed 86-Operated 94 Relay Operated		MW MVAR	Open Close
Line Incoming Circuit Switcher	Urgent Alarm Non-Urg. Alarm 86 Dc supply lost	Open/ Closed 86-Operated			
Power Transformer	Local / Remote SCADA Auto/ Manual Master Follower Independent Urgent Alarm Non-Urg. Alarm 86 Coil supply lost AVR Auto / manual	86-T Operated	MWH	MW MVAR Tap-Changer Position	SCADA Auto SCADA Manual Master Follower Independent Raise Lower
Bus Incoming Circuit Breaker	Local / Remote Urgent Alarm Non-Urg. Alarm 86 Dc supply lost Selected to trip	Open/ Closed 86-Operated 94 Relay Operated			Open Close Select to trip Select to trip reset
Bus Tie Breaker	Local / Remote Auto / Manual Urgent Alarm Non-Urg. Alarm 86 Dc supply lost ATS Auto/ manual Selected to trip	Open/ Closed 86-Operated			Open Close ATS SCADA Auto ATS SCADA manual Select to trip Select to trip reset
Bus				KV Frequency (Optional)	
Motor Feeder Breakers 5000 hp & above	Open / Closed Tripping Relay 94 (Optional) Dc supply lost	Motor protection package Operated (Optional) 94 Relay Operated			

Table 3 – SCADA Standard Point List (Cont'd)

Express Feeder Breaker	94 DC supply lost 86 DC supply lost Local / Remote Urgent Alarm Non-Urg. Alarm	Open / Closed 86-Operated Tripping relay (94) Operated		MW MVAR	Open Close
Station Service Transformer Feeder Breaker		Open / Close			
Feeder Breaker Less than 5000 hp	Open / Close (optional) Tripping Relay 94 (Optional) 86 Dc supply lost	Open/ Closed Motor protection package Operated (Optional) 94 Relay Operated			
Station	Abnormal		Revenue Meter (KWH)		
Battery & Battery Charger	Abnormal				

Table 4 – SCADA RTU Analog Description

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• K. Volts	• Line • Bus	**SCADA RTU** shall have provisions to be interfaced to the Metering system directly to provide the required point.
• M. Watts • M. Vars	• Power Transformer • Line • Express feeders	**SCADA RTU** shall have provisions to be interfaced to the Metering system directly to provide the required points.
• Tap Position	• Transformer equipped with AOLTC (Automatic On Load Tap Changer)	AOLTC shall be equipped with two resistor banks. One resistor bank will transmit tap position to local transformer control panel inside the substation building, while the second will transmit tap position to **SCADA RTU**. The size of the resistor bank to be used for **SCADA RTU** shall be 2000.00 ohm, all resistors must have equal size and connected between the tap positions, the resistor rating is ¼ watt. The DC supply (0-5VDC) is from RTU power supply module.

Table 5 – SCADA RTU Control Point Description

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• Open • Close	• Line Incoming, Bus Incoming, Tie Circuit Breakers express feeders and CP O/H lines breakers.	Each individual circuit breaker must be equipped with a Local/Remote switch; each close or open command must go through a dedicated Remote contact from a dedicated Local/ Remote switch. Amber light must not illuminate when breaker is opened via SCADA.
• Select to trip • Select to trip reset	• Bus incoming & tie circuit breakers	Central Dispatchers are able to select a breaker to be opened first before attempting to parallel the scheme by closing the third breaker. The selected breaker will be opened automatically, after time delay, when the third breaker is closed. The scheme shall be reset to normal by a separate control command
• SCADA Manual • SCADA Auto • Raise • Lower	• Transformer equipped with AOLTC (Automatic On Load Tap Changer)	Central Dispatchers are able to raise or lower transformer Tap position only when they disable transformer Automatic Voltage Regulator (AVR) with the manual command. An auxiliary relay is required for this function, which will be disabled through an Auto command.
• SCADA Manual • SCADA Auto	• Automatic Transfer Scheme (ATS)	Central Dispatchers are able to disable substation ATS scheme, with the Manual command. An auxiliary relay is required for this function, which will be disabled through an Auto command.
• Master • Independent	• Transformers which are operated in parallel as a master/follower (usually in normally closed bus tie SWGR set-up)	Master/ Follower/ Independent indication points must show actual status of Local/Remote operation modes.

Table 6 – SCADA RTU ACC Point Description

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• Revenue readings (KWH)	• Substation	SCADA RTU shall have provisions to be interfaced to the substation revenue meter
• M. Watt-Hours	• Line • Power Transformers	**SCADA RTU** shall have provisions to be interfaced to the Metering system directly to provide the required point.

Table 7 – SCADA RTU SOE Point Description

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• 86 (lockout) Operated Protection Relay Operated	• Transformers • Circuit Breakers • Circuit Switchers • Buses	
Open/Closed	• H. V. breakers, cir-switchers, Incoming & Tie Cir. Breakers. • CP O/H breakers • Express Feeder • Motor Feeder breakers for motors > 5000 HP	

Table 8 – SCADA RTU Status Point Description

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• Local /Remote (Supervisory)	• Line Circuit Breakers • Bus Incoming & Tie Circuit Breakers • Power Transformers • CP O/H breakers • Express feeders	Each equipment must be equipped with a Local / Remote switch to disable SCADA control operations when equipment is operated locally at the station. One remote dry contact from each individual equipment must be wired to **SCADA RTU** for indication.

Table 8 – SCADA RTU Status Point Description (Cont'd)

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
Urgent Alarms: 1) For each individual Circuit Breaker & Switcher, the following summary alarms must be paralleled: • Loss of tripping circuit DC supply • Loss of protection DC supply • Circuit Breaker Trip coil • Loss of motor operating supply • Loss of air or SF6 gas pressure • SF6 Gas Blocking • SF6 Gas Refilling, and Pump Motor Running • Microprocessor-based relay failure (for breakers) 2) For each individual Power transformer, the following summary alarms must be paralleled: • Combustible gases present • Pressure relief • Buchholz relay operated • Sudden pressure • High winding temperature	• Line Circuit Breakers & Switchers • Bus Incoming & Tie Circuit Breakers • Power Transformers • Substation	• All urgent alarms shall be segregated and indicated as urgent.

Table 8 – SCADA RTU Status Point Description (Cont'd)

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
Non-Urgent Alarm 1) For each individual Circuit Breaker & Switcher, the following summary alarms must be paralleled: • Loss of closing circuit supply • Circuit breaker Closing coil • Loss of air or SF6 gas pump supply 2) For each individual Power transformer, the following summary alarms must be paralleled: • Loss of referential potential on AVR • Loss of cooling fans supply • Low transformer oil • High oil temperature • Low/High tap Changer oil level • Loss of tap changer motor operating supply • Loss of tap changer control supply • Tap Changer failure • Intrusion	• Line Circuit Breakers & Switchers • Bus Incoming & Tie Circuit Breakers • Power Transformers Substation	

Table 8 – SCADA RTU Status Point Description (Cont'd)

POINT DESCRIPTION	EQUIPMENT	END DEVICE REQUIREMENTS
• Auto / Manual	• Power Transformer ALTC • Bus Automatic Transformer Schemes	• Auto contact of Auto / Manual switch or relay must be wired to SCADA for indication. Cases where Auto/ Manual switch and Auto/ Manual Relay are implemented for an individual control circuit, Auto contacts must be wired in parallel.
• Master • Follower • Independent	• Power Transformer ALTC (Applicable in substation where planned or being operated with a normally closed Bus Tie Circuit Breakers)	• Each indication point must indicate actual (Master, Follower, or Independent) operating mode regardless of Local/ Remote switch position.
• Open/ Close	• Outgoing & Station Service Transformers Breakers feeders • Less than 5000 hp motor feeder circuit breakers (Optional)	
• Abnormal	• Substation • Battery Charger	1) The following substation alarms must be wired to **SCADA RTU** as a summary alarm point:: • Switchgear Bldg. High Temperature • Fire or Smoke Detector 2) The following Battery Charger alarms must be wired to **SCADA RTU** as a summary alarm point: • Loss of AC Supply • Low DC Voltage • Low Charging Rate Ground on DC System

8.3 The **IFC**, where both field and **SCADA RTU** cables are terminated, shall be located adjacent to the **RTU** (side by side). 1.5 meter workspace is required in front and 1.0 meter in back of the **RTU**.

8.4 A minimum of 20% spare point's of control, analog, SOE shall be provided to accommodate future operational field additions.

8.5 Communication shall be coordinated with Saudi Aramco Comm's Operns. & Maint. Dept. to ensure that their work schedules are compatible.

8.5.1 A telephone type terminal box or distribution frame is to be mounted on the interior wall of the Switchgear Building and will serve as an interface

between the outdoor and indoor communications cables. Communication protection equipment may be required depending on the calculated Ground Potential Rise of the substation.

8.5.2 Indoor cabling will consists of a 6 twisted par cable with an overall shield to handle **SCADA** and voice communications. This cable will be routed from the distribution frame to the **IFC** and terminated at both locations by the station designer.

8.5.3 A vertical mounting telephone is to be fixed on or inside the **IFC**.

8.6 **SCADA** drawings shall be prepared and submitted for review before finalizing. Drawings shall be of 28" X 20" size. One complete package shall have the following:

8.6.1 Table of Contents: This will list all the **SCADA** design drawings by sheet number. Presently, all the drawings of any one package have the same drawing number with identification by sheet number.

8.6.2 Standard Symbols and Details: These drawings are a summary of legends describing the symbols used in the **SCADA** drawings.

8.6.3 Remote Station Function Tabulation: These sheets list the **SCADA** points by absolute point number. Each category (Status, **SOE**, Accumulator, Analog, and control) is given a separate sheet. **RTU** scanning and point allocations are also shown.

8.6.4 **SCADA** Function Diagram: This is a simplified one-line diagram for the station showing each piece of equipment connected to the **SCADA** system. Details on this drawing shall include those listed below:

a) Electrical Equipment Numbers obtained from **PDD** Chief Dispatcher.

b) CT and P.T. ratios and their connection to **SCADA** and synchronizing circuits. Information supplied shall be complete and allow the calculation of scale factors.

c) **SCADA** functions at each device defined by symbols.

d) Transformer tap details

In a general way represent the **SCADA** interface within the substation.

8.6.5 **RTU** Configuration Sheet: This is a summary sheet indicating the type of modules, controller assignment, and the number of points that are used or spared in each module.

8.6.6 **SCADA** Summary Sheet: This drawing will have a listing by absolute point number of the field termination, the associated functions prepared under this phase of design, **RTU** cable identification, signal identification, point location within the **RTU** and scan information.

8.6.7 Elementary Drawings: These drawings will indicate the specific field interface connection points and cable and wire identification for each status, SOE, accumulator, analog and control points.

8.7 Each **SCADA** point-type shall utilize dedicated cables. Wires of different point-type shall in no case share the same field cable. Low signals analog cables shall be shielded. All **SCADA** field cables shall meet Saudi Aramco standards.

8.8 Field contacts shall be dry (No external voltage) contacts dedicated to **SCADA.** Contacts from alarms shall be normally closed, alarming on an open state. Annunciator auxiliary contacts shall not be used for alarms to **SCADA**, except when the alarm is a direct function of the annunciator. The condition that exists on the closure of a contact for status shall be noted in the Function Tabulation drawings.

8.9 Discrete measurements (transducers) shall not be used for required **SCADA RTU** analog points such as Volts, Watts, etc. These points, however, are available through data link to the Power Monitoring System.

8.10 **SCADA RTU** installation shall include:

8.10.1 Physical installation of the **RTU** and **IFC**.

8.10.2 Wiring from all field points to terminal blocks in the **IFC**.

8.10.3 Wiring from **RTU** to communications interface.

8.10.4 AC and DC power wiring.

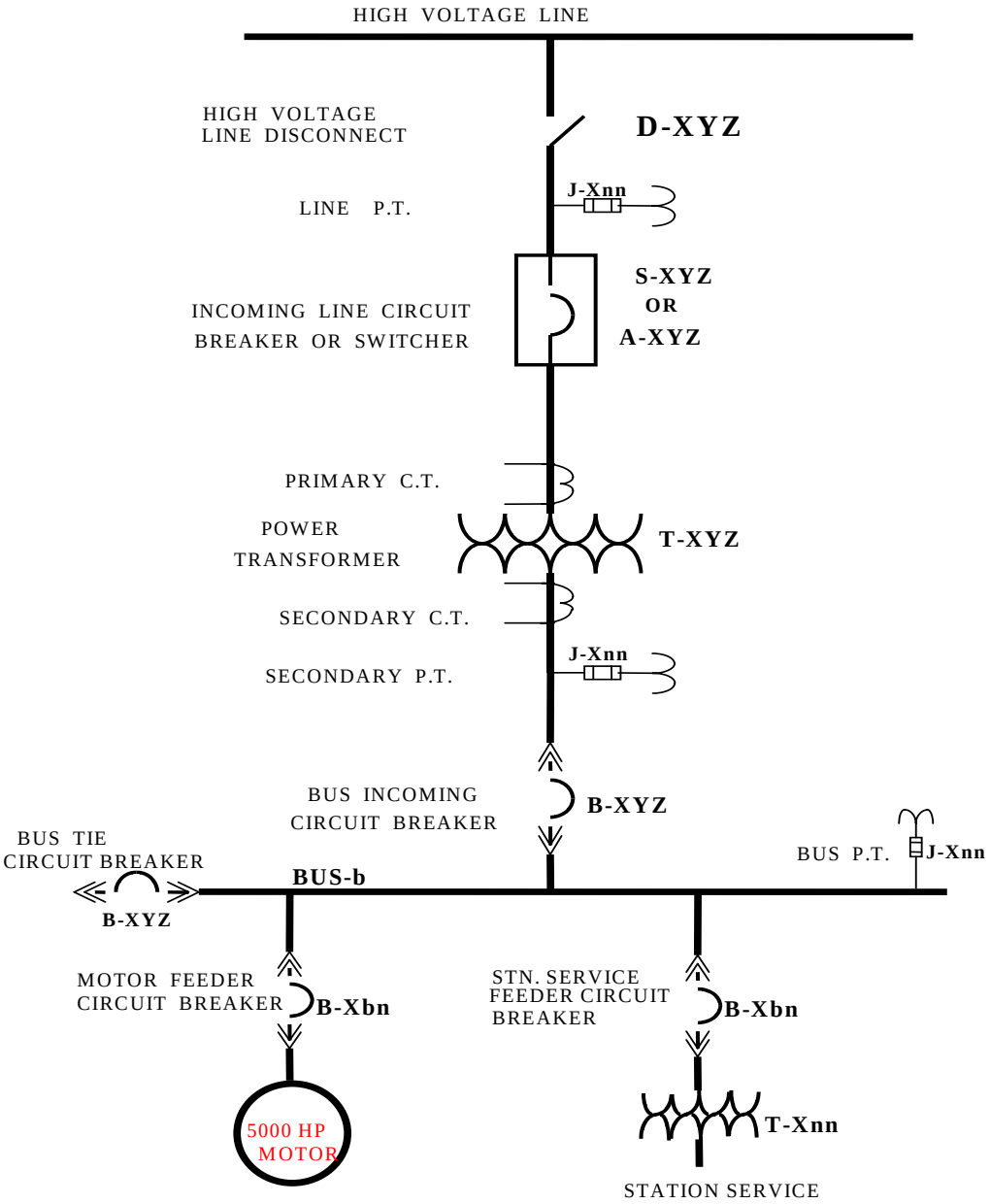
8.10.5 Grounding

8.11 SCADA RTU setup, pre-commission and commission shall be coordinated with **PDD** Planning & Technical Services Division.

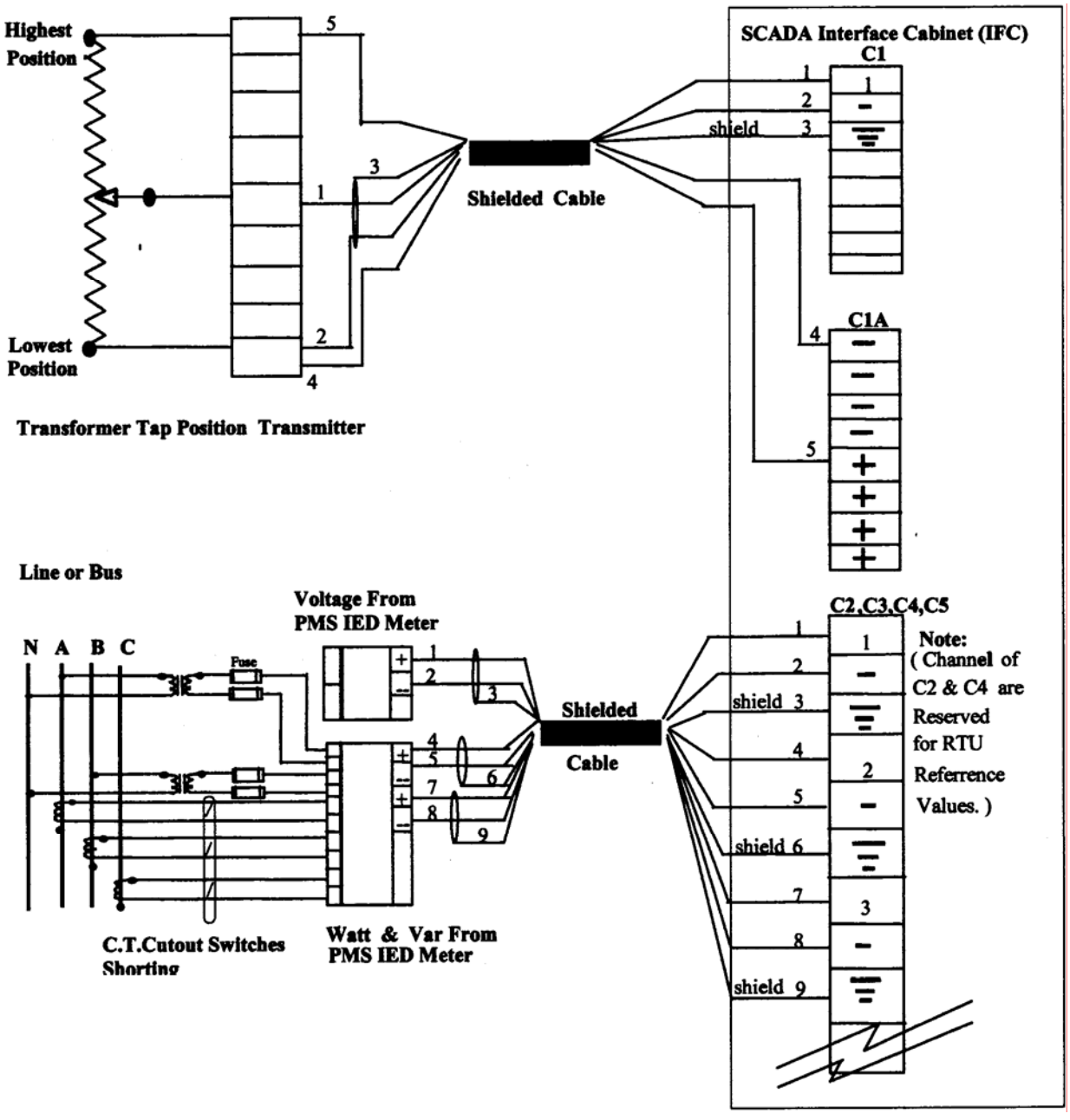
Revision Summary

31 May 2004 Major revision.
30 March 2005 Minor revision.

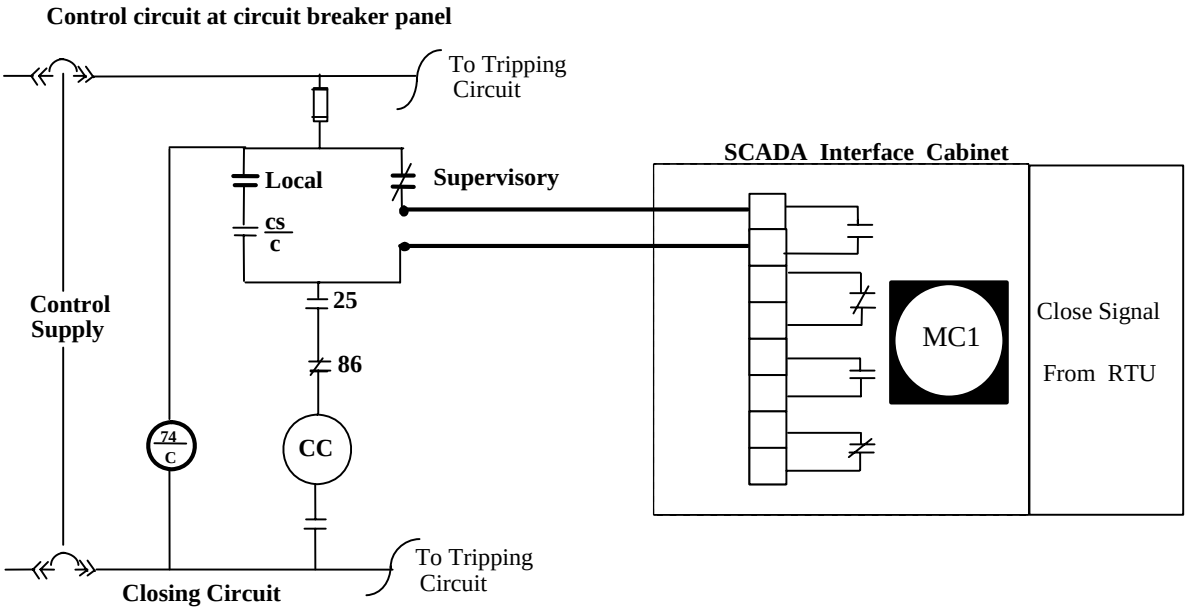
Attachment 1 – SCADA Electrical Equipment Definitions

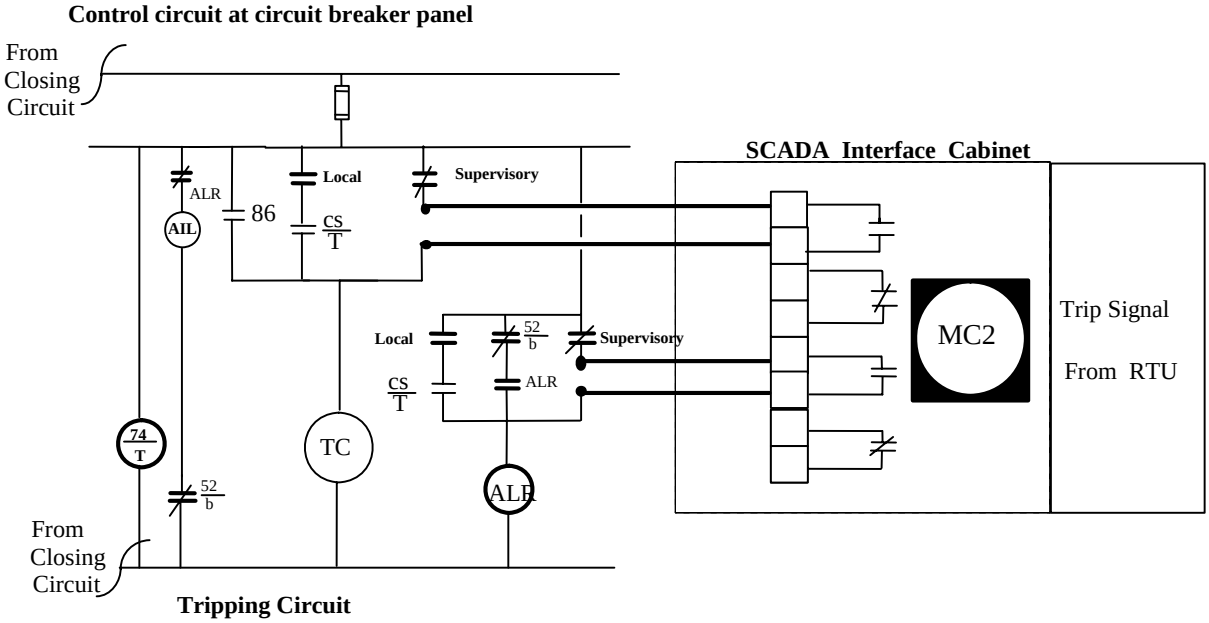


Attachment 2 – SCADA Wiring & Connection for the Transformer Tap Changer Position, Voltage, Watt, & Var



Attachment 3 – SCADA Wiring & Connection for Circuit Breaker Closing & Tripping Circuit





Attachment 4 – SCADA Wiring & Connection for the Transformer Tap Changer Control Circuit