Engineering Standard

SAES-P-114 5 December 2012

Power System Protection and Control

Document Responsibility: Electrical Systems Designs and Automation Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This Standard prescribes the mandatory requirements for the design of protective relaying and control for power systems and equipment. This document may not be attached to nor made a part of purchase orders.

2 Conflicts and Deviations

2.1 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.

2.2 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 to the Manager, Consulting Services Department of Saudi Aramco, Dhahran requesting his approval.

2.3 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-P-100 *Basic Power System Design Criteria*

SAES-P-121 *Transformers and Reactors*

SAES-P-126 *Power System Automation*

Commentary Note:

SAES-P-126 is not specifically referred to in the body of SAES-P-114. However, there are many overlapping functional requirements and similarities between the scopes of these two documents. Design of protective and control schemes are mainly dependent on the two documents.

Saudi Aramco Materials System Specifications

16-SAMSS-502	*Metal-Enclosed, Metal-Clad 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-507	*High Voltage Motor Controller - Outdoor*
16-SAMSS-512	*Outdoor Switchrack - Low Voltage*
16-SAMSS-513	*Power System Automation Components*
16-SAMSS-517	*Adjustable Frequency Drive System - 1 kV and Above*
17-SAMSS-510	*Form-Wound Synchronous Turbine Generators*
17-SAMSS-518	*Diesel Generator Sets*

Saudi Aramco Library Drawings

DD-950114 : Series Sheets 1 through 38

3.2 Industry Codes and Standards

American National Standards Institute

ANSI C37.2	*Electrical Power System Device Function Number*
ANSI C37.91	*Guide for Protective Relay Applications to Power Transformers*
ANSI C37.101	*Guide for Generator Ground Protection*
ANSI C37.102	*Guide for AC Generator Protection*

Institute of Electrical and Electronics Engineers

IEEE 446	*Emergency and Standby Power Systems for Industrial and Commercial Applications*
IEEE C37.113-1999	*Guide for Protective Relay Applications to Transmission Lines*

ANSI/IEEE C57.13	*Standard Requirements for Instrument Transformers*

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*

International Electrotechnical Commission

IEC 255	*Electrical Relays*
IEC 61850	*Communication Networks and Systems in Substations*
IEC 61000	*Electromagnetic Compatibility (EMC)*
IEC 60044	*Instrument Transformers*

4 General

4.1 Where "DD-950114/X" is mentioned, this is a Saudi Aramco Library Drawing. The "X" designates the sheet number. These drawings present typical information which complements this standard. They are not mandatory.

4.2 Protection requirements for specific equipment is covered within the applicable Saudi Aramco Materials System Specifications (SAMSSs) and Saudi Aramco Engineering Standards (SAES's).

4.3 General Protection Philosophy

1) Protective relaying systems shall be applied throughout the power system to detect undesirable or intolerable operating conditions, and to disconnect the troubled areas or equipment from the other sections of the power system.
2) The Industry Standards listed in Section 3 of this SAES shall be used for additional guidance, explanation, and definition of the protection schemes.
3) Protection zones shall overlap, to ensure complete protection at the zone boundaries.
4) Protective relays may be used for multiple functions including metering, alarming and control.
5) Main and local back-up protection of an equipment shall be provided using different protective device manufacturers.

4.4 Mandatory Standards and Policies

1) System and equipment protection shall conform to NFPA 70, as supplemented by this Standard.

2) Protective device function number definitions and applications shall conform to ANSI C37.2.

4.5 Review Responsibilities

1) Protection and control schemes, auto-transfer schemes, synchronization, islanding, and load shedding schemes for all circuits rated above 1000 V, and equipment rated 480 V and above including trip units (digital or Solid-State trip devices) or microprocessor based relays in switchgear assembly shall be reviewed and concurred to in writing by the Coordinator, Power System Planning & Engineering Department.

2) Final protective relay device settings and fuse ratings for all circuits including trip units (digital or Solid-State trip devices) or Microprocessor based relays shall be issued by the Coordinator, Power System Planning & Engineering Department.

4.6 Protection System Design Package Requirements

The design package for protection and control systems shall provide the following information as a minimum:

1) Relay and Metering One-Line Diagrams, Saudi Aramco.

2) AC and DC Elementary (Schematic) Diagrams, Saudi Aramco and Vendor.

3) AC Three-line (Connection) Diagrams, Saudi Aramco and Vendor.

4) Interconnection Diagrams, Saudi Aramco and Vendor.

5) Panel Wiring Diagrams.

6) Synchronizing Diagrams.

7) Relay and control panel layout drawings, Saudi Aramco and Vendor.

8) Power System Automation package including equipment layout drawings, communication/networking configuration, architecture, and control logic and ladder diagrams.

4.7 Instrument Transformer

4.7.1 Instrument transformer sizing and calculation study shall be completed for all new or modified power system installations. The study shall be completed for all projects and submitted for review no later than the 30% detailed design review.

4.7.2 For revenue metering, a dedicated metering class CT shall be provided.

4.8 Protection System Settings and Coordination Studies

4.8.1 Protection system settings and coordination studies shall be completed for all new or modified power system installations.

4.8.2 A preliminary protection system settings and coordination study shall be completed for all projects and submitted for review no later than the time of the 90% detailed design review.

4.8.3 A final protection system settings and coordination study shall be completed and submitted for review at least two months prior to commissioning of the electrical equipment.

4.8.4 The final protection system coordination study shall be completed using ETAP STAR unless otherwise approved by the Coordinator, Power System Planning & Engineering Department.

4.8.5 The final protection system settings and coordination study review package shall include:

a) A hard and electronic copy of the final protective system coordination study with all required setting parameters.

b) Recommended final device settings including copy of the device software data files.

c) Protective device data: manufacturer, style, model, type, range, and time characteristic curves. Protective device and plant data shall refer to the actual devices supplied on the project. General catalog extracts or typical data are not acceptable, full manuals are required.

d) Nameplate data and ratings of motors, buses, generators, power conductors, instrument transformers, power transformers, and cables (including cable short-circuit withstand limits).

e) Data for motors over 100 HP shall include the following: Horsepower rating; Nameplate voltage; Full load current; Locked rotor current; Acceleration time at 80%, 90%, 100% and Permitted stall time at 80%, 90%, 100%, 110% of rated voltage; Thermal capability curves(Hot/Cold); Number of starts allowed, from cold (cold start) in first hour and subsequent hours; After running trip (hot start), starts allowed in first hour and subsequent hours. If acceleration time exceeds permitted stall time, data on speed switch and timers shall be provided; RTD data.

f) Data for generators shall include: Rating, positive, negative and zero sequence impedances, negative sequence capability, minimum motoring power, over frequency curves, thermal capability curve, decrement curve, time constants.

4.9 Coordination and Settings of Main Protection

4.9.1 The calculations, settings, and coordination of the main or primary system protection shall be based on the following two operating conditions:

a) Minimum fault current

b) Maximum fault current

4.9.2 The maximum fault duration time allowed by the protection shall not exceed the short-circuit withstand capability of the protected equipment.

4.9.3 The Coordination Time Interval (CTI) between time-overcurrent relays shall not exceed 0.35 seconds at maximum transient fault current.

4.9.4 The CTI between coordination pairs of a time-overcurrent relay and a trip unit (digital or Solid-State device), a fuse or an instantaneous relay shall be 0.25 seconds at maximum transient fault current.

4.9.5 The CTI between coordination pairs of trip unit (digital or Solid-State device) and fuses shall be 0.1 sec at maximum transient fault current.

4.9.6 The calculations for subtransient fault currents shall include the contribution from both synchronous and induction machines, while transient fault calculations shall include synchronous machines only.

4.9.7 Subtransient current values shall be used in calculating the settings and coordination of the following units:

a) Instantaneous relays.

b) Overcurrent relays with less than 0.1 second operating times.

c) Fuses with minimum-melting times less than 0.1 second.

4.9.8 Transient current values shall be used in calculating the settings and coordination of the following units:

a) Overcurrent relays with 0.1 second or more operating times.

b) Fuses with minimum-melting times of 0.1 second or more.

4.9.9 The settings of instantaneous units that are sensitive to DC offset current shall be based on the maximum DC offset current in the protected circuit.

4.9.10 Where a local or remote backup protection is provided by the utility company, backup protection coordination with the Saudi Aramco protection shall be provided

4.10 Relay Selection

Protective relays shall be selected from the approved protective relay devices listed in 16-SAMSS-513 or applicable SAMSS of switchgear and control gear.

5 Motor Protection

Motor protection requirements are covered within the applicable Saudi Aramco Materials System Specifications (SAMSSs) to which the equipment is connected. Specifically:

1) Low Voltage Switchgear –16-SAMSS-502
2) Low Voltage Controlgear –16-SAMSS-503
3) High Voltage Switchgear –16-SAMSS-504
4) High Voltage Controlgear, Indoor – 16-SAMSS-506
5) High Voltage Controlgear, Outdoor – 16-SAMSS-507
6) Low Voltage Switchrack –16-SAMSS-512
7) High Voltage Adjustable Frequency Drive –16-SAMSS-517

6 Generator Protection

Generator protection requirements that must be supplied by the generator skid vendor is specified within the specific generator material specification. (e.g., 17-SAMSS-510 “Brushless Synchronous Generators”, 17-SAMSS-518 “Diesel Generator Sets”).

6.1 General

a) The following ANSI Standards shall be consulted for additional guidance, explanation, and definition of the protection schemes required in this section:

Reference A: ANSI C37.101 Guide for Generator Ground Protection

Reference B: ANSI C37.102 Guide for AC Generator Protection

b) For other than Standby/Emergency generators, where protection functions are provided by an integrated package, redundancy must be provided. As a minimum, phase and ground overcurrent shall be provided by other relays or other packages.

6.2 Large Direct-Connected Synchronous Generators

6.2.1 Refer to DD-950114/1 for the typical required protection for large direct-connected synchronous generators with a kVA rating greater than 12,500 kVA.

6.2.2 The neutral grounding for the generator shall be low resistance type as described in ANSI C37.101, Table 1, Grounding Method III (Low Resistance).

6.2.3 The minimum required generator protection schemes for ground faults are described in ANSI C37.101, Table 1, Generator Connection E. Also, refer to DD-950114/1 for a typical scheme.

a) Scheme 10 (Primary-connected CT with time-delay ground overcurrent relay) plus

b) Scheme 16 (Percentage differential and polarized neutral overcurrent).

6.2.4 Dual multifunction protection relays from two different manufacturers shall be used as listed in 16-SAMSS-513.

6.3 Large Unit-Transformer Connected Synchronous Generators

6.3.1 Refer to DD-950114/2 for the typical protection for large unit-transformer connected synchronous generators with a kVA rating greater than 12,500 kVA.

6.3.2 The type of neutral grounding for the generator shall be high resistance type as described in ANSI C37.101, Table 1, Method I (Distribution Transformer Grounded - High Resistance).

6.3.3 The minimum required generator protection schemes for ground faults are described in ANSI C37.101, Table 1, Generator Connection E. Also, refer to DD-950114/2 for a typical scheme.

a) Scheme 1 (Ground overvoltage) plus

b) Scheme 5S (Starting ground overvoltage) plus

c) Scheme 10 (Primary-connected CT with time-delay ground overcurrent).

6.3.4 Dual multifunction protection relays from two different manufacturers shall be used as listed in 16-SAMSS-513.

6.4 Medium Size Direct-Connected Synchronous Generators

6.4.1 Refer to DD-950114/3 for the typical protection for medium size direct-connected synchronous generators with kVA ratings greater than 1000 but not exceeding 12,500 kVA.

6.4.2 The type of neutral grounding for the generator shall be low resistance type as described in ANSI C37.101, Table 1, Grounding Method III (Low-Resistance).

Commentary Note:

For LV generator neutral grounded shall be solidly connected to ground.

6.4.3 The minimum required generator protection schemes for ground faults are described in ANSI C37.101, Table 1, Generator Connection E. Also, refer to DD-950114/3 for a typical scheme.

a) Scheme 10 (Primary-connected CT with time-delay ground overcurrent) plus

b) Scheme 16 (Percentage differential and polarized neutral overcurrent).

6.4.4 Dual multifunction protection relays from two different manufacturers shall be used as listed in 16-SAMSS-513.

6.5 Standby/Emergency Generators

This section provides general protection requirements for low voltage standby / emergency, diesel-engine driven generators.

6.5.1 Where built-in protection is provided by the generator manufacturer, the protection for generators above 250 kW shall be subject to approval in accordance with paragraph 4.5.

6.5.2 The generator's purpose and classification as emergency, standby, or both, shall be determined by the project proponent in accordance with NFPA 70, and IEEE 446, Emergency and Standby Power Systems.

6.5.3 Protection and control schemes shall be reviewed and concurred to in writing by the Coordinator, Power System Planning & Engineering Department.

6.5.4 The generator protection scheme shall be compatible with the following generator, exciter, and system parameters:

a) Type of Excitation System

b) Magnitude and duration of generator fault currents

c) Generator short-circuit withstand capability

d) Coordination with downstream protective devices

6.5.5 Where a generator system is supplied with a molded-case main circuit breaker, the breaker shall have a continuous current rating not exceeding 125% of the generator's rated capacity.

6.5.6 Where a low-voltage main power circuit breaker is used, the breaker shall have a continuous current rating not less than the generator maximum rating. When a circuit breaker integral protection device is provided, it shall have long-time, short-time phase, and instantaneous units. A separate ground fault relay shall alarm only and its sensor (CT) shall be capable to withstand the maximum ground fault current continuously.

6.5.7 The Vendor shall supply the following generator data for review and for use in calculating the relay settings:

a) Nameplate ratings.

b) Short-circuit test data showing the magnitude and duration of fault currents for various types of faults on the generator terminals.

c) Type and characteristics of excitation system.

d) Short-circuit withstand capability (I^2T).

e) Built-in protection devices that are supplied as part of the generator assembly.

7 Transformer Protection

7.1 General

7.1.1 Refer to Section 8 of SAES-P-121 for protection devices and schemes that shall be applied to power and distribution transformers installed in Saudi Aramco facilities.

7.1.2 Where the protection requirements for a transformer type or application are not specifically covered in this Section or in SAES-P-121, the

Coordinator, Power System Planning & Engineering Department, shall determine the required protection scheme and devices.

8 Bus Protection

8.1 General

This section specifies the protection requirements for buses rated 480 V or higher.

8.1.1 The zone of protection shall include the connected circuit breakers, disconnecting switches, and instrument transformers, where possible.

8.1.2 Refer to Section 4 for the general requirements of the protective devices and schemes.

8.2 Bus Protection Schemes

One or more of the following bus protection schemes shall be provided:

8.2.1 A bus differential scheme (Device 87B) shall be installed on the following types of buses:

a) All switchgear buses rated 4.16 kV and above.

b) Generator buses rated 2.4 kV and above, which are connected to other sources or in parallel with other generators or a power system.

8.2.2 A phase and ground overcurrent scheme shall be installed on the incomer and bus tie breakers on the following types of buses:

a) As primary protection where the bus does not require a differential or partial differential scheme.

b) As backup protection to Device 87B differential scheme where a partial differential backup scheme is not required.

8.2.3 Where there is a normally connected alternate source to the bus, a hand-reset tripping and lockout relay shall transfer-trip the remote circuit breakers of the alternate source via a self-reset tripping and lockout relay which shall have a target to indicate the source of the trip.

8.2.4 Where there is a normally connected alternate source on the bus side (e.g., double ended switchgear), an inter-locking scheme shall be provided to prevent closing bus incomer breaker while the source side breaker is in open condition.

8.2.5 Differential Scheme

a) The Device 87B bus differential relays shall be high-impedance type, with independent measuring units for each phase.

Exception:

Low impedance bus differential scheme is allowed for transfer bus arrangement through disconnects.

b) For transfer bus arrangement through disconnect the followings are required:

i) Protection schemes that do not require switching of current transformer feeds shall be specified.

ii) An overall check zone differential scheme shall be applied for each bus couples. Both the overall check zone and the individual protection shall operate. Each differential shall be equipped with a two way switch: in service and test.

Commentary Note:

Putting the switch on test position shunt the trip contacts and leave the bus protected by other differential scheme.

c) When low impedance bus differential protection is used for bus transfer arrangements, the check zone protection shall be provided internally as an integrated function of the relay.

d) The differential relays shall trip a dedicated (86B) lockout relay.

e) Refer to DD-950114/19 for a typical scheme.

Commentary Note:

The bus differential for high voltage systems of 69 kV and above may not be installed in substation configuration where all the buses or connection nodes are covered by redundant feeder or line protection such as in PI, Inverted PI, or Ring bus configurations.

8.2.6 Overcurrent Scheme

a) A bus overcurrent scheme shall provide either a) a set of phase and ground overcurrent relays (Devices 51 & 51G including 51NL and 51NB), or b) an Integrated Breaker Trip Device on each incomer and the bus-tie breaker for buses rated 1000 V or less. Device 51N shall be wired to neutral CT when available.

Commentary Note:

Incomer and bus-tie ground overcurrent relays (Devices 51NL and 51NB) shall be wired to the transformer neutral CT where available. Also, the 51G included in the incomer and bus tie breakers may be used to provide the functions of 51NB and 51NL.

b) Where the incomer to a bus is fed from a transformer, the phase and ground overcurrent relays or Integrated Breaker Trip Device that provide the transformer secondary circuit protection (see Section 7) shall also provide the bus protection. Duplication of incomer and bus protection is not required.

c) Refer to DD-950114/21,22 for a typical scheme.

8.3 Bus Lockout functions

8.3.1 Bus differential protection relay shall trip and lockout all breakers connected to the bus and block the automatic bus transfer scheme as per the guideline of Section 11.

8.3.2 Trip-isolation test switches shall be installed in the relay tripping circuits to the circuit breakers.

8.3.3 The continuity of the external lockout relay for bus differential shall be monitored by a monitoring relay.

8.4 Current Transformers for Differential Schemes

8.4.1 All current transformers used in differential or partial differential schemes shall use the same tap ratio and shall have compatible excitation and saturation characteristics and shall conform to the relay manufacturers' requirement. For multi-ratio CT's used in differential or partial differential schemes, the full-winding CT ratio shall be used.

8.4.2 The CT's for bus differential schemes shall not be used for other relaying or metering circuits.

8.4.3 Shorting-type test switches for the current transformers shall be provided for each CTs. See DD-950114/24 for typical connections of high impedance protection.

Commentary Note:

For high impedance bus diff connection, after approval by Coordinator, Power System Planning & Engineering Department, a common CT Field Test (FT) switch may be used for the overall CT connection at the relay in leiu of individual FT's.

9 Line and Circuit Protection

9.1 General

This section specifies general relay protection requirements for radial and inter-tie overhead or underground transmission, sub-transmission, and distribution lines and circuits. Radial lines are defined as when short circuit occurs in the lines, there is a flow of current from one end only representing the source side. There is no flow in the load side except for possible transient motor contributions. Inter-tie lines are defined as when short circuit occurs in the line, there is a sustained flow of current from both ends of the lines.

Commentary Note:

> *Parallel circuits originating from the same substation to a facility are considered as inter-tie lines.*

9.1.1 Line protection shall include the line breakers in the protection zones.

9.1.2 The AC voltage input to directional, impedance, or distance-type relays shall be protected with 3-pole molded-case circuit breakers.

9.1.3 The AC voltage input to impedance or directional distance type relays shall be obtained from VT's on the bus side of the circuit breaker, where available. Where directional distance relays must be connected to VT's on the line or load side of the circuit breaker, a bolted fault scheme shall be provided.

9.1.4 Radial and inter-tie lines operating at 69 kV and above shall have two redundant protection sets as will be explained in sections 9.2 and 9.3.

9.1.5 Whenever communication media for line protection is required, fiber optics shall be applied.

9.1.6 Directional ground overcurrent relays on lines and circuits shall be preferably voltage and current dual-polarized type, and both polarizing quantities shall be used, where available.

9.1.7 The zero sequence polarizing voltage for directional ground relays shall be obtained from either broken-delta connection of VT secondary windings or auxiliary voltage polarizing transformer connected to the VT secondary windings.

9.1.8 The zero sequence polarizing current for directional ground relays shall be obtained from transformer neutral CT's. Where there is a possibility of incorrect polarizing from neutral CT's and an autotransformer or multi-winding transformer is available, polarizing current shall be obtained from CT's inside the delta or tertiary winding.

9.1.9 All 115 kV and above inter tie lines protection shall have the capability to ride through system stable swings conditions.

9.2 Protection of Radial Lines

9.2.1 Radial Lines less than 69 kV

The following protection shall be applied:

9.2.1.1 Feeder microprocessor package with phase and ground overcurrent protection.

9.2.1.2 Lines extended over desert areas shall be provided with an additional sensitive ground fault protection that can either be part of the feeder protection package as required in 9.2.1.1 or a separate relay. The relay shall detect downed conductors lying on dry ground. The relay shall block auto reclosing, where provided.

9.2.2 Radial Lines 69 kV and Above

The following protection shall be applied:

9.2.2.1 For lines rated 69 kV up to 132 kV, one set of distance relay protection backed up by phase and ground overcurrent protection provided by a separate relay at the source side.

9.2.2.2 For lines rated 230 kV and above, two sets of distance relay protection each backed up by phase and ground overcurrent protection that can be integrated in the distance protection relay.

Commentary Note:

Differential relays may be used in lieu of distance relays for the radial protection if pilot communication system is available and it is anticipated for future modification in accordance with 9.3.

9.2.2.3 For short lines with source to line impedance ratio (SIR), as defined by IEEE C37.113-1999, equal to 4.0 or above, differential protection shall be applied instead of distance protection in 9.2.2.1 & 9.2.2.2 above. Back up protection shall remain the same as given in these two items above.

9.2.2.4 For submarine cables, two sets of differential protection package. Each differential protection shall be backed up with built in backup phase and ground directional overcurrent protection at source end.

9.2.2.4 For circuits connected to downstream systems including transient or steady-state current sources such as large synchronous machines-motors/generators or highly capacitive/reactive system, the protection system shall be in accordance to 9.3.

9.2.2.4 Transmission lines terminating directly to power transformers without breakers shall have transfer trip from transformer protection which shall operate faster than the line protection to block line reclosing.

Commentary Note:

This includes transmission lines with transformers equipped circuit switcher.

9.3 Protection of Inter-tie Lines

9.3.1 General

Line breakers closing shall be through synch check relays connected to the VT's of the intertie systems.

Commentary Note:

The synch check function may be an integral part of the protective devices.

9.3.1 Inter-tie Lines less than 69 kV

The following protection shall be applied:

- Feeder digital protection relay with phase and ground directional overcurrent protection at both ends.

9.3.2 Inter-tie Lines Rated 69 kV

The following protection shall be applied:

9.3.2.1 One differential protection backed up with phase and ground directional overcurrent protection provided by an external relay.

9.3.2.2 For submarine cables, two sets of differential protection. Each differential protection shall be backed up with built in backup phase and ground directional overcurrent protection at both ends.

9.3.3 Inter-tie Lines 110 kV and Above

The following protection shall be applied:

9.3.3.1 For lines with source to line impedance ratio (SIR), as defined by IEEE C37.113-1999, equal to 4.0 or above, two sets of differential protection shall be applied with built in back up phase and ground step distance protection at both sides. In addition, ground directional overcurrent protection operating in directional comparison shall be applied. The directional ground overcurrent can be built in the line protection.

9.3.3.2 For lines with source to line impedance ratio (SIR) is less than 4, either differential protection as in 9.3.3.1 or two sets of communication assisted distance protection with switch on to fault capability (SOTF) shall be applied.

9.3.3.3 Cable circuits shall be protected by differential protection scheme as in 9.3.3.1 regardless of the SIR level. Submarine cables shall be protected as in Section 9.3.2.2.

Commentary Note:

Transmission lines which interties to generation or cogeneration facilities shall be equipped with out-of-step relays for system separation in case of non-recoverable system swings. The out of step scheme can be built in function in the line protection relay.

9.4 Ungrounded Lines and Circuits (see SAES-P-100 for limitation)

9.4.1 The phase fault protection for ungrounded circuits shall be the same as required for grounded systems.

9.4.2 A ground fault detection and alarm scheme shall be installed on all ungrounded circuits. The type of scheme shall depend on broken delta connection of VT secondary windings for fast identification of the grounded feeder or phase. A non-selective scheme shall be applied to systems where it is allowable for the location of the fault to be determined by the systematic switching out of individual circuits. See DD-950114/35,36 for a typical scheme.

9.5 Polarizing Currents and Voltages

9.5.1 Directional ground overcurrent relays on lines and circuits shall be preferably dual-polarized type, and both polarizing quantities shall be used, where available.

9.5.2 The zero sequence polarizing voltage for directional ground relays shall be obtained by one of the following methods:

a) Broken-delta connection of VT secondary windings

b) Auxiliary voltage polarizing transformer connected to the VT secondary windings.

9.5.3 The zero sequence polarizing current for directional ground relays shall be obtained from transformer neutral CT's. Where there is a possibility of incorrect polarizing from neutral CT's and an autotransformer or multi-winding transformer is available, polarizing current shall be obtained from CT's inside the delta or tertiary winding.

9.6 Automatic Reclosing

Automatic reclosing shall not be provided, except where warranted by high probability of successful reclosure and a low probability of additional disturbance to the power system.

10 Breaker Failure Protection

10.1 General

This section specifies the local breaker failure protection requirements for circuit breakers.

10.1.1 Local breaker failure protection shall be provided for all HV circuit breakers rated 69 kV and above.

10.1.2 The Breaker Failure (BF) scheme shall include the following:

10.1.2.1 BF initiation system by the protection relays

10.1.2.2 Phase and ground fault current detection by BF over-current relay (50BF). For low current faults (e.g., downstream short circuit), the BF may be initiated directly by the tripping relays such as 86T.

10.1.2.3 Two stages operation are required: 1) A re-trip attempt of the faulty breaker via a timer (62BF-1, 0-150 msec) and self reset relay (94BF) and 2) Tripping of all adjacent breakers via a timer (62BF-2, 0-300 msec) and hand-reset relay (86BF).

Commentary Note:

When the main and back-up tripping circuits trip both trip coils of the breaker, then one stage operation is required to trip all adjacent breakers via a timer (62BF, 0-150 msec) and hand-reset relay (86BF).

10.1.2.4 The 86BF tripping circuit may utilize the bus differential or line/feeder protection lockouts to trip all adjacent breakers, after Power Systems Planning & Engineering Department approval.

10.1.2.5 The 50BF may be an integral part of the circuit breaker protection

10.2 Breaker Failure Schemes

10.2.1 General

Refer to DD-950114/37 for a typical breaker failure scheme that shall be applied to high voltage circuit breakers.

10.2.2 Breaker Failure Lockout Relays

Trip-isolation test switches shall be provided in the breaker trip circuits from the Devices 94BF and 86BF lockout relays.

11 Automatic Transfer System

11.1 Double-ended switchgears as per 16-SAMSS-502/16-SAMSS-504 shall have an Automatic Transfer Scheme (ATS).

11.2 ATS controller output relays shall be used for tripping and closing of circuit breakers and annunciation to SCADA, DCS, Annunciator and PSA.

12 Generation Control, Interconnectivity and Islanding

“Islanding” operation occurs when Saudi Aramco facility or part of the facility, connected to its in-house power generation plant, becomes electrically isolated from the Utility Grid or other power plants but the facility’s full or partial load continues to be fed from the in-house power generation plant.

12.1 Islanding Detection

Islanding detection system shall be provided for all Saudi Aramco facilities with in-house power generation plant and normally connected to the grid or other power plant.

The islanding condition shall be detected using both of the following two methods:

12.1.1 Detection of full physical isolation from the Utility grid by detecting the position of all circuit breakers leading to islanding including the Utility Grid substation.

12.1.2 Use of locally available transient power system parameters such as frequency, voltages and/or current to detect islanding condition.

The islanding detection method shall be reliable, fast, dependable and secure (capable to discriminate with non-islanding events).

12.2 Load Shedding

12.2.1 Load shedding shall be provided for fast removal of amount of plant's load in response to generation deficiency during islanding and other system conditions in order to keep the remaining portion of the electrical system operational and maintain stability and frequency within its limits.

Commentary Note:

For those Saudi Aramco facilities which are normally running on island mode, a generation deficiency detection and load shedding facilities shall be provided if they are specified in the project specific documents.

12.2.2 Load shedding basic requirements:

i) The load to be shed shall be dynamically pre-defined in real time by calculating and identifying the lowest priority load that match the generation gap.

ii) The load priorities shall be modified dynamically in order to adapt to load availability and distribution network configuration.

iii) Immune to nuisance tripping.

iv) Load shedding shall take place within the stability time limits determined through stability study and islanding time requirements.

v) The amount of load to be shed need to be communicated to the turbine controller within the time limit specified by the turbine manufacturer.

vi) A back up multi-stages under-frequency based load shedding scheme shall also be provided.

vii) Both main and back up load shedding systems shall remain operational during system island operation.

12.3 Load Rejection

12.3.1 Load rejection shall be provided for fast removal of excess plant's generation during islanding and other system conditions in order to keep the electrical system operational and maintain stability and frequency within its limits.

12.3.2 Load rejection basic requirements:

i) The generation to be shed shall be dynamically pre-defined in real time.

ii) The generation shedding priorities shall be modified dynamically in order to adapt to operation, power and steam requirements.

iii) Generation shedding or run back shall take place within the stability time limits determined through stability study and islanding time requirements.

12.4 Generation Control Basic Requirements

For a smooth transition from grid connected operation to island operation the following minimum design criteria need to be satisfied:

12.4.1 In the event of separation from the Utility grid or other power plant provider, the in-house power plant is required to support uninterrupted power supply to the Saudi Aramco facility.

12.4.2 Separation from Utility Grid (Or other power plant provider) can occur at different levels of power export or import to the Utility Grid (or other power plant provider). The in house power plant AVR and Governor Controller needs to be equipped with the required functionality to ensure correction and restoration of the voltage and frequency to their nominal value during Islanding operation without affecting the system stability.

12.5 Back-Synchronization

After transition to islanding operation, it is required to synchronize back the in-house power plant to the Utility grid (or the other power generation plants). Back synchronizing capabilities shall be made available at each interconnection circuit breaker which may lead to islanding operation. A synch check relay, located at each back synch circuit breaker and a PCC permission shall be used to close the breaker(s).

12.6 Studies and Simulations

Islanding, load shedding and/or generation run back real time dynamic simulation (or equivalent software tool) using high-fidelity model of power generation equipment shall be carried out, considering site specific control system logic and application software. The developed simulation model is intended to study all potential island mode operating scenarios and test system functionalities over the entire operating range. Simulation scenarios shall be developed in conjunction with Saudi Aramco.

12.7 Islanding and Load Shedding Testing

Actual Islanding, Load shedding, generation run back and back synch shall be field tested to fully validate the interaction of each individual islanding control function including the turbine electrical system and steam delivery system.

12.8 Utility Grid Separation

Frequency relays are required to be installed at the tie point with the Utility in order to initiate separation from the Grid in order to protect Saudi Aramco critical processing facilities from major Grid network disturbances that may lead to Grid collapse. The setting parameters of the frequency relay shall be determined considering the following factors:

i) The overall system (facility and cogeneration power plant) stability during and after the grid network disturbance.

ii) The frequency settings recommended by Utility.

iii) The frequency variation limits as per the Saudi Arabian Grid Code.

iv) The final settings shall be discussed and approved by the utility authority and/or other power plant providers where applicable

	Revision Summary
5 December 2012	Major revision.