Engineering Standard

SAES-P-114 29 September, 2004

Power System and Equipment Protection

Saudi Aramco DeskTop Standards

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Primary contact: Ali M. Al-Qahtani on 873-1334

1 Scope

This Standard prescribes minimum mandatory requirements for the design and installation of protective relaying 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 applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

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 such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

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-116	*Switchgear and Control Equipment*

Saudi Aramco Materials System Specification

16-SAMSS-513	*Protective Devices*

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 C37.90	*Relays and Relay Systems Associated with Electrical Power Apparatus*
ANSI C37.91	*Guide for Protective Relay Applications to Power Transformers*
ANSI C37.93	*Guide for Protective Relay Applications of Audio-Tones Over Telephone Channels*
ANSI C37.95	*Guide for Protective Relaying of Utility-Consumer Interconnections*
ANSI C37.97	*Guide for Protective Relay Applications to Power System Buses*
ANSI C37.101	*Guide for Generator Ground Protection*
ANSI C37.102	*Guide for AC Generator Protection*
ANSI C37.106	*Guide for Abnormal-Frequency Protection for Power Generating Plants*
ANSI C57.12.80	*Terminology for Power and Distribution Transformers*
IEEE C57.91	*Guide for Loading Mineral-Oil-Immersed Transformers*

Institute of Electrical and Electronics Engineers

IEEE 100	*Standard Dictionary of Electrical and Electronic Terms*
IEEE 141	*Recommended Practice for Electric Power Distribution for Industrial Plants*
IEEE 142	*Recommended Practice for Grounding Industrial and Commercial Power Systems*
IEEE 242	*Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*
IEEE 281	*Service Conditions for Power System Communication Equipment*
IEEE 446	*Emergency and Standby Power Systems for Industrial and Commercial Applications*

IEEE 602	*Recommended Practice for Electric Systems in Health Care Facilities*

National Electrical Manufacturers Association

NEMA PB 2.2	*Application Guide for Ground Fault Protective Devices for Equipment*

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*
NFPA 110	*Emergency and Standby Power Systems*

Insulated Cable Engineers Association

ICEA P-32-382	*Short Circuit Characteristics of Insulated Cable*
ICEA P-45-482	*Short Circuit Performance of Metallic Shielding and Sheaths of Insulated Cable*

International Electrotechnical Commission

IEC 255	*Electrical Relays*

Underwriters' Laboratories, Inc.

UL 1053	*Ground Fault Sensing and Relaying Equipment*

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) to which the equipment is connected.

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.

4.4 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 schemes, auto-transfer schemes, and underfrequency load shedding schemes for all circuits rated above 1000V, incomers and bus ties rated 480 V and above and all feeders including Solid-State trip devices (SST) or microprocessor based relays in switchgear assembly shall be reviewed and concurred to in writing by the Coordinator, Power Distribution Engineering Division, Power Distribution Department.

2) Final protective relay device settings and fuse ratings for all circuits rated above 1000 V , incomers and bus ties rated 480 V and above, and all feeders equipped with Solid State Trip (SST) devices or Microprocessor based relays in switchgear assembly shall be issued by the Coordinator, Power Distribution Engineering Division (PDED), Power Distribution Department (PDD).

4.6 Protection System Design Package Requirements

The design package for control and protection 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.

4.7 Protection System Coordination Studies

4.7.1 Protection system coordination studies shall be completed for all new or modified power system installations.

4.7.2 A preliminary system coordination study shall be completed for all projects and submitted for review no later than the time of the 90% detailed design review. This study shall contain data and detail necessary to validate selection of the protective devices and instrument transformers used with the protection system.

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

4.7.4 The final system coordination study shall be done using ETAP PowerPlot unless otherwise approved by the Coordinator, Power Distribution Engineering Division (PDED), Power Distribution Department.

4.7.5 The final system coordination study review package shall include:

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

b) Recommended final device settings.

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). 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%; Permitted stall time at 80%, 90%, 100% and 110% rated voltage; Thermal capability curves(Hot/Cold); Number of starts allowed, from cold in first hour and subsequent hours; After a running trip, 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.

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.

4.8 Protective Device Requirements

4.8.1 Specific hardware and firmware requirements for protective relays are indicated within the applicable Saudi Aramco Materials System Specifications of the equipment within which the relays will be installed. Approved relays are listed in 16-SAMSS-513.

4.8.2 Device numbers in the standard are function references. Multiple functions may be provided in one assembly unless specifically excluded. When a backup protection is required, it shall be provided by a separate assembly.

4.8.3 Connection to local DCS system, if provided, shall allow read only.

4.8.4 The relay self check feature shall alarm to the DCS or SCADA system.

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) Normal minimum system

b) Normal maximum system

4.9.2 The coordination time interval (CTI) between coordination pairs of time-overcurrent relays shall be within the range of 0.35 to 0.50 second at normal maximum transient fault current.

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

4.9.4 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.

4.9.5 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.

4.9.6 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.

4.9.6 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.

4.10 Coordination and Settings of Backup Protection

4.10.1 Whenever a backup protection is provided, it shall be set to protect against relay, breaker, or fuse failures.

4.10.2 Upstream backup protection shall coordinate with downstream protection over the range of normal minimum to normal maximum fault currents.

4.10.3 Where a local or remote backup protection is provided by the Saudi Electric Company (SEC), the SEC Electric System Protection Division shall be requested to provide backup protection and coordination with the Saudi Aramco protection.

5 Motor Protection

5.1 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, some 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 voltage rating of 13.8 kV or above and 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 voltage rating of 13.8 kV or above and 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 a voltage rating of 1000 to 13,800 volts and 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).

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 Small Standby/Emergency Generators

This section provides general protection requirements for small 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 review in accordance with Paragraph 4.4.

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 The minimum protection shall consist of phase overcurrent and ground overcurrent, protection devices.

6.5.4 The type of ground fault protection required for emergency generators shall be subject to review in accordance with Paragraph 4.4.

6.5.5 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

6.5.6 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.

6.5.7 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 and short-time phase units only. A separate ground fault relay shall alarm only and its sensor (CT) shall be capable to withstand the maximum ground fault current continuously.

6.5.8 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).

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

6.6 Relay Selection and Functions

Relays for generator protection shall be selected from those listed in 16-SAMSS-513. Refer to DD-950114/1,2,3 for typical schemes.

7 Transformer Protection

7.1 General

7.1.1 This Section specifies the 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, the Coordinator, Power Distribution Engineering Division, Power Distribution Department, shall determine the required protection scheme and devices.

7.1.3 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.

7.2 Transformer Protection Schemes

The following sections specify the required protective relay schemes for the various types of transformers and transformer applications.

7.2.1 Step-Down, Two-Winding, Power Transformers

The typical protection schemes for step-down, two-winding, power transformers with self-cooled ratings greater than 772 kVA are shown in the Library Drawings listed in Table 1.

Table 1 – Step-Down, Two-Winding, Power Transformers

	HV-LV Winding Connections	DD-950114/12
Normally-Open LV Bus Tie	Delta-Wye	4
	Wye-Delta, with LV Gnd. Xmfr	5
	Delta-Delta	6
	Delta-Delta, with LV Gnd. Xmfr	7
Normally-Closed LV Bus Tie	Delta-Wye, Greater Than 600 V	8
	Delta-Wye, 600 V or less	9
	Wye-Delta, with LV Gnd. Xmfr	10

Commentary Note:

Per SAES-P-116, bus tie breakers are not permitted to be operated Normally-Closed (NC). The information in Table 1 is to provide the requirements for existing NC bus tie systems.

7.2.2 Generator Step-Up and Auxiliary Station Service Transformer

The protection scheme for a unit-connected generator step-up power transformer, and associated auxiliary station service transformer connected to the generator leads, is given in Section 6.

7.2.3 Multi-Winding Power Transformer

The typical protection scheme for a three-winding power transformer is shown in DD-950114/11. Four-winding protection requirements are the same as for three-winding transformers, except additional relays are required on the fourth leg of the transformer.

7.2.4 Intertie Autotransformer

The typical protection scheme for an intertie autotransformer is shown in DD-950114/12.

7.2.5 Pad-Mounted Distribution Transformer

The protection required for a pad-mounted distribution transformer rated 750 kVA or less shall be phase and ground overcurrent relays at the high side circuit breaker. Refer to Section 7.4 to determine if fuse protection is allowed on the HV side of the distribution transformer in lieu of relays and a breaker.

7.2.6 Pole-Mounted Distribution Transformer

The HV side of an overhead pole-mounted distribution transformer shall have an expulsion fuse cutout (or fuse link).

7.2.7 Grounding Transformer

Refer to DD-950114/5,7,10 for the typical protection scheme for grounding transformers on LV side delta connected windings.

a) The Device 50/51XT phase overcurrent relays shall be connected to a set of delta-connected current transformers, and shall allow a time overcurrent pickup setting of 1.25 times the continuous current rating of the grounding transformer.

b) The 51N neutral overcurrent relays shall allow a pickup setting of 10 to 20% of the 10-second current rating of the grounding transformer for low resistance grounding system. For solidly grounded system the relay shall allow a pickup of 10% or less pf the transformer rating.

7.2.8 Banked Transformers

Where two or more transformers are fed by a common breaker on the HV side and a common breaker on the LV side, the following protection schemes shall be installed:

a) Where the individual transformers have approximately equal percent impedances on their own bases, a set of three, phase-overcurrent relays and one, ground- overcurrent relay shall be connected to CT's on the HV-side breaker. The HV phase overcurrent relays shall allow a pickup setting of approximately 1.3 times the sum of the rated currents of the banked transformers. Instantaneous element shall allow a setting of max of the following:

   i) Inrush of the combined transformer with DC offset (through fault with DC offset)

   ii) 110% of minimum melting current of the maximum current limiting fuse

b) Where the HV side of banked transformers is rated above 1000 V, and each transformer does not have individual HV-side relays, the LV-side of each transformer shall have a set of phase and ground protective devices.

7.2.9 Multiple Transformers on Radial Feeders

Where two or more transformers are connected along a common feeder circuit (at the same or different locations) and the feeder is served from a remote circuit breaker, each transformer shall have one of the following HV-side protection schemes located at the transformer:

a) HV-side relays with transfer-trip to the remote breaker.

b) HV-side relays and local HV-side circuit breaker or fault interrupting circuit switcher.

c) HV-side fuses, where allowed by Section 7.4.

Refer to the appropriate section of this section for the required protection scheme and relays for each transformer size and type on the feeder circuit.

7.2.10 Captive or Dedicated Transformer

The transformer protection shall be basically as specified in the other sections of this section for a normal transformer with the same kVA rating, voltage, and winding connections; however, motor relays which are connected to the HV side of the transformer shall give combined protection to the transformer and motor. See DD-950114/18 for a typical protection scheme. For medium voltage motors the transformer neutral shall be high resistance grounded through the primary of a distribution transformer. The secondary shall be shunted by a resistor. A ground fault overvoltage relay shall be connected across the resistor, and shall trip the high side circuit breaker.

7.2.11 HV Circuit Switcher

a) Refer to DD-950114/13 for a typical transformer protection scheme where a circuit switcher is provided in lieu of a HV circuit breaker or fuses.

b) Where the available fault current can exceed the interrupting rating of the circuit switcher, a trip blocking scheme shall be installed to prevent damage to the circuit switcher when the fault current exceeds the interrupting rating. Remote relays and breakers shall be required to detect and clear fault currents that exceed the circuit switcher interrupting rating. A time delay relay (0.2 to 2 seconds) shall be included in the blocking scheme to force-trip the circuit switcher if remote relays or breakers do not interrupt the fault. Refer to DD-950114/14 for a schematic diagram of the typical blocking scheme.

7.2.12 Transfer-Trip to Remote Breakers

a) Where the fault interrupting device is not located at the transformer, a transfer-trip circuit shall be installed from the transformer relays to the remote breaker. This shall be provided by a dedicated channel which shall provide high speed operation. Transfer trip systems, other than those using direct control wiring within the facility, shall have channel monitoring which shall alarm at a manned location. Direct wired transfer trips shall be via a 94 relay which shall have a target to indicate the source of the trip.

b) Where the power transformer is protected by remote relays and there is a normally connected alternate source on the low side, an auxiliary hand-reset lockout relay located at the remote relay panel shall also transfer-trip local circuit breakers at the transformer.

7.3 Protection Device Applications Requirements

The protection schemes and relays shown in the Library Drawings and described in the sections above shall be applied as follows:

7.3.1 Differential Relays

a) General Requirements

i) A three phase percentage differential relay with inrush restraint shall be installed on power transformers with a self-cooled rating 5,000 kVA and above.

ii) Where transformers are operated in parallel, and each transformer meets the kVA criteria for differential protection, each transformer shall have a separate set of differential relays.

iii) Where a grounding transformer is connected within the differential zone, as in DD-950114/5,7,10, a zero sequence current shunt shall be installed to prevent false operation during external ground faults. Refer to DD-950114/15 for typical installation.

iv) The differential relays shall contain a separate restraint circuit for each winding of the transformer, and each breaker in a multiple-breaker service shall be connected to a separate restraint circuit.

b) Current Transformers for Differential Relays

i) The differential zone shall include the HV and LV-side circuit breakers, (where possible) by connecting the 87T relays to CT's on the line side of the HV-side circuit breaker (where available) and to CT's on the load side of the LV-side circuit breaker (where available). See DD-950114/4 for a typical configuration.

ii) The CT current rating (neglecting the CT's continuous thermal current rating factor) shall not be less than the

maximum continuous force-cooled current rating of the transformer.

7.3.2 Phase Overcurrent Relays

General Requirements:

a) Phase overcurrent relays (Device 50/51H) shall be installed on the HV side of transformers rated above 1000 V, where the transformer is fed by a circuit breaker or circuit switcher, but shall not be installed where the transformer is protected by fuses. The relays shall be connected to CT's on the source side of the circuit breaker, where available.

b) Phase overcurrent relays (Device 51L, 50/51L) shall be installed on the LV side of transformers, where the LV winding is rated above 600 V. The relays shall be connected to CT's on the transformer side of the circuit breaker, where available. Where LV is connected to an incomer feeding multiple loads, instantaneous element (device 50) shall not be provided.

c) Integrated Breaker Trip Device units (Device 50/51SST) shall be provided in the circuit breakers in lieu of relays on the HV side of transformers rated 1000 V or less. Integrated Breaker Trip Device units shall be installed in the circuit breakers on the LV side of transformers rated 1000 V or less in lieu of relays. All Integrated Breaker Trip Device units shall include the following adjustable elements:

   i) Long Time (Adjustable pickup and time delay)

   ii) Short Time (Adjustable pickup and time delay)

   iii) Instantaneous (Do not provide, or deactivate, on LV side Integrated Breaker Trip Devices)

   iv) Ground Unit (Adjustable pickup and time delay)

d) The pickup setting of the relay time-overcurrent unit or the Integrated Breaker Trip Device long-time unit shall not exceed the maximum allowable pickup values in NEC Article 450-3 for Supervised Installations, and the setting percentages given in NFPA 70 Table 450-3(a)(2)(b) shall apply to the transformer self-cooled rating.

e) The time-current characteristic of the protection on the HV side shall coordinate with the transformer through-fault protection

curves over the calculated range of fault currents as required by ANSI C37.91 for infrequent fault duty type of service. It shall also coordinate with the time-current characteristics of the LV-sides devices.

f) Protective devices on the HV-side of a transformer feeder shall coordinate with the time-current characteristics of the LV-side devices.

7.3.3 Ground Overcurrent Relays

a) General Requirements

i) A ground overcurrent relay (Device 50G, 50/51GN) shall be installed on the HV side of transformers rated above 1000 V, where the transformer is protected by a circuit breaker or circuit switcher, but shall not be installed where the transformer is protected by fuses. For residual CT connection, the 50/51GN pickup shall allow setting of 10% of transformer forced cooling rating and a minimum time delay of 0.1 sec at or below 400% of transformer self cooling rating.

ii) Ground fault units shall be provided in the Integrated Breaker Trip Device devices for the circuit breakers on the HV side of transformers rated 1000 V or less, but shall not be installed where the transformer is protected by fuses.

iii) Ground fault units shall be provided in the Integrated Breaker Trip Device devices for the circuit breakers on the LV side of transformers, where the LV winding is rated 1000 V or less. Where LV is connected to an incomer feeding multiple loads, instantaneous element shall not be provided.

b) Ground Sensors and Window-Type CT's

i) A sensitive instantaneous ground overcurrent relay (Device 50G) shall be installed on the circuit feeding the HV side of the transformer, where the HV winding is delta-connected, or ungrounded wye-connected, and a single window-type CT can be fitted around all three phases. The CT ratio shall be selected to limit the maximum relay current to 50 A.

ii) Where a single window-type CT cannot be fitted, a ground overcurrent relay (Device 50/51G) shall be connected in the phase overcurrent CT circuit.

c) Neutral Overcurrent Relays

i) One neutral overcurrent relay (Device 51NT) shall be connected to a CT in the neutral of all grounded neutral, wye-connected, 480 V, power transformer windings, except where the transformer is protected by fuses on the HV side, and there is no dedicated HV circuit breaker or the HV circuit breaker is too remote for direct tripping.

ii) Where the LV winding is rated 1000 V or greater, three separate neutral overcurrent relays, (51NT, 51NB, 51NL) shall be installed. For a typical connection, refer to DD-950114/8.

iii) The neutral overcurrent relays shall allow pickup settings approximately 10% higher than the highest pickup setting of the ground relays on the LV bus outgoing feeders. The time-overcurrent curves of the neutral overcurrent relays shall allow a coordination time interval of 0.35 to 0.50 second with the curves of the ground relays on the LV bus outgoing feeders at the maximum LV normal transient fault current. Instantaneous element (50) shall not be provided or it shall be deactivated.

iv) The current rating of the transformer neutral CT shall be 100% or greater of the winding self-cooled current rating for solidly-grounded transformers, and not more than 50% of the resistor 10-second current rating for neutral resistance grounded transformers.

d) Restricted Earth Fault or Directional Ground (Device 67TG)

A restricted earth fault (ground differential) relay (device 87N) shall be installed to protect the grounded-wye transformer windings. Refer to DD-950114/8,9,10,11 for a typical configuration.

An 87N or 67TG relay shall provide sensitive protection for the windings and incomer for any LV system operating condition when a zero sequence source on the LV bus.

7.3.4 Directional Phase Overcurrent Relays (Device 67L)

Directional phase overcurrent relays (Device 67L) with instantaneous and time overcurrent units shall be installed on the LV side of transformer connected to buses with normally-closed bus ties or normal LV sources. The Device 67L directional relays shall look toward the transformer. See DD-950114/8,9,10,11 for a typical configuration. The relay pickup shall allow a setting of 10% forced air cooling rating of the transformer. The instantaneous element shall allow a setting of a reverse through fault current with DC offset.

Commentary Note:

Per SAES-P-116, bus tie breakers are not permitted to be operated Normally-Closed (NC). This information provides the requirements for existing NC bus tie systems.

7.3.5 Ground Fault Detector for Ungrounded Systems (Device 59V0)

Where an autotransformer tertiary or LV winding of a two-winding step-down power transformer is delta-connected or ungrounded-wye connected, and a grounding transformer is not provided, a zero sequence overvoltage ground fault detection scheme shall be installed. Refer to DD-950114/6,12 for a typical installation.

7.3.6 Pressure-Rise Relays (Device 63T, 63GT)

Where a Buchholz or Sudden Pressure relay is provided, a 63X auxiliary target relay shall be located on the transformer relay panel in the substation control room. The 63X relay shall trip an 86T hand-reset lockout relay. The 63T/63X relay shall always trip a separate lockout relay from 87T relays. Where an 87T differential relay is not provided, the 63T relay shall trip the 86T1 lockout, and the remaining relays the 86T2 lockout.

7.3.7 Overtemperature Devices (Device 49T)

a) The winding hot-spot temperature measuring device shall initiate an overtemperature alarm, but shall not trip the transformer circuit breakers.

b) The top-oil temperature measuring device shall initiate an overtemperature alarm, but shall not trip the transformer circuit breakers.

7.3.8 Low oil level indication.

Where a low fluid level indicator is provided, it shall give an alarm on low oil level. This device shall also trip through an auxiliary target relay (71X), if trip on low oil function is not provided by the 63 device. The trip level shall be 5% below the alarm level, or as recommended by the transformer manufacturer. The target relay (71X) shall be located on the transformer relay panel.

7.3.9 Lockout Relays (Device 86T1, 86T2, 87T3)

a) Hand-reset lockout relays (Device 86) shall trip and lockout the HV and LV-side circuit breakers.

b) A minimum of two separate lockout relays are required for each power transformer. The main and backup relays shall trip separate lockout relays. Main and backup lockout relays shall trip separate breaker trip coils where dual trip coils are provided.

c) Trip-isolation test switches shall be installed in the trip circuits from the 86T lockout relays.

d) Lockouts shall block the automatic transfer scheme. Lockout relays which operate for transformer faults only shall not block auto transfer.

7.4 Fuse Protection of Transformers

7.4.1 General Requirements

a) HV-side fuse protection is allowed on 69 or 115 kV delta-connected windings where the self-cooled OA rating is below 5,000 kVA.

b) HV-side fuse protection is allowed on delta-connected transformers where the voltage is less than 69 kV and the OA rating is less than 2,000 kVA.

c) Fuses shall not be installed on transformer primary windings that are connected in grounded-wye, or on autotransformer series or common windings.

d) Individual transformers of banked transformers shall not be protected by fuses.

e) HV-side fuses shall not be provided in lieu of breakers to protect transformers with low resistance-grounded neutrals or grounding transformers on the LV side.

f) Where fuses are installed on the HV side of a transformer, separate overcurrent protection devices shall be installed in the LV circuit. These may be at the service entrance in residential installations.

g) The fuse manufacturer's application data shall be consulted to obtain the required fuse style and rating for each application.

7.4.2 Fuse Ratings

a) The symmetrical interrupting rating of a fuse shall not be less than maximum symmetrical subtransient fault current at the transformer.

b) The interrupting rating of current-limiting type fuses shall be based on the available fault current and not on the let-through current characteristic of the fuse.

c) The continuous current rating of a fuse shall be greater than the continuous full-load current rating of the transformer. The required rating shall be selected such that the fuse will not melt or deteriorate during force-cooled loading or magnetizing inrush conditions.

d) The minimum-melting time-current characteristic shall coordinate with the transformer inrush current.

e) The fuse maximum continuous current rating shall be as specified by NEC Article 450-3 Table 450-3(a) (2) for Supervised Locations.

f) The selection of the fuse continuous current rating shall allow for the higher than standard ambient air temperatures specified in SAES-P-100, and the effect of pre-fault full-load current.

7.4.3 Installation Requirements

a) Where expulsion fuses are mounted separately or as part of an expulsion fuse cutout, the manufacturer's recommended minimum phase-to-phase and phase-to-ground clearances shall be followed, but the clearances shall not be less than the minimum clearances in ANSI C37.46.

b) Where fuses are located in an enclosure, the fuse manufacturer shall supply a revised current rating or the applicable derating factor.

7.4.4 Fuse Coordination

a) For the normal maximum transient fault current, the minimum coordination time interval between upstream relays and downstream fuses shall be 0.25 second, and between upstream fuses and downstream relays shall be 0.35 second.

b) The total-clearing time-current characteristic of the fuse shall coordinate with the transformer through-fault protection curve for minimum and maximum normal fault currents, in accordance with ANSI C57.91 or the transformer manufacturer's data.

8 Bus Protection

8.1 General

This section specifies the protection requirements for buses rated 480V 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 three 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 13.8 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 Differential Scheme

a) The Device 87B bus differential relays shall be high-impedance type, with independent measuring units for each phase. 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 ontest position shunt the trip contacts and leave the bus protected by other differential scheme.

b) Where the bus rating is 115kv and above, and bus transfer is not applied, two differential schemes shall be specified for each bus. Each differential scheme shall have dedicated current transformer and their contacts are wired in shunt. There should be a two position test switch for each differential scheme; in-service, and test position.

Commentary Note:

Putting the switch in test position shall isolate the trip signals.

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

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

8.2.5 Overcurrent Scheme

a) A bus overcurrent scheme shall provide either a) a set of phase and ground overcurrent relays (Devices 51 & 51G), or b) a Solid State Trip Integrated Breaker Trip Device on each incomer and the bus-tie breaker for buses rated 1000 V or less. The Integrated Breaker Trip Device shall not have instantaneous trip. Device 51N shall be wired to neutral CT when available.

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 incomer protection (see Section 6)

shall also provide the bus protection. Duplication of incomer and bus protection is not required.

c) Neutral ground protection (for low voltage system), device 51NB (for High voltage system) in addition to the bus phase and ground overcurrent relays (51 and 51G) shall trip a dedicated 86B lockout relay.

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

8.3 Bus Lockout Relays

8.3.1 Bus protection lockout relay (Device 86B) shall trip and lockout all breakers connected to the bus and block the automatic bus transfer scheme (where provided).

Commentary Note:

Where controlgear assembly is directly connected with switchgear assembly and the controlgear is covered by the bus differential protection zone, the bus protection lockout relay (86B) shall not trip the contactors.

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

8.3.3 The continuity of the lockout relay for bus differential shall be monitored by a 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 For outdoor switchyard buses rated 69 kV or above, the CT leads from each breaker shall be brought to a switchyard junction box located approximately equidistant from each of the breaker CT's. See DD-950114/23 for typical connections. Test switches for the current transformers shall be installed in the junction box. The test switches shall be shorting-type such as States Co., Type MTS or equivalent. See DD-950114/24 for typical connections.

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 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 section 9.2.

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.

9.2 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 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 69kV or 115 kV, one set of differential protection backed up by phase and ground overcurrent protection provided by an external relay at the source side.

9.2.2.2 For lines rated 230 kV, two sets of differential protection backed up with at least one set of phase and ground overcurrent protection at the source side. The set can be integrated in one of the differential protection.

9.2.2.3 For submarine cables, two sets of differential protection package. At least one set shall have built in backup phase and ground directional overcurrent protection at source end.

9.3 Protection of Inter-tie Lines

9.3.1 Inter-tie Lines Less Than 69 kV

The following protection shall be applied:

Feeder microprocessor package 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 package. At least one set shall have built in backup phase and ground directional overcurrent protection at both ends.

9.3.3 Inter-tie Lines 115 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 standard C37.113-1999, equal to 4.0 or above, two sets of differential protection package 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 9.3.2.1 or two sets of directional phase and ground distance protection with switch on fault capability (SOF) shall be applied.

9.3.3.3 Cable circuits shall be protected by differential protection scheme as in 9.3.2.1 regardless of the SIR level.

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 the following circuit breaker applications:

All HV circuit breakers rated 69 kV and above.

10.1.2 A separate Device 62BF timer shall be used for each circuit breaker with breaker failure protection.

10.1.3 Refer to Section 4, for general requirements of relays and schemes.

10.2 Breaker Failure Schemes

10.2.1 High Voltage Circuit Breakers (69 kV or Above)

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

10.2.2 Transformer Breakers (69 kV or Above)

The breaker failure timer for transformer breakers shall be initiated by the Device 86T transformer lockout relays. See DD-950114/37 for a typical scheme.

10.2.3 Breaker Failure Lockout Relays

Trip-isolation test switches shall be provided in the breaker trip circuits from the Device 86BF lockout relays. See Section 4 for details of the test switches.

10.3 Relay Selection

For the selection of Breaker Failure Relays, refer to 16-SAMSS-513. See DD-950114/37,38 for typical information.

11 SCADA System Requirements

Refer to SAES-P-119 for SCADA system requirements.

Revision Summary

29 September, 2004 Major revision.