Engineering Standard

SAES-P-121 31 July, 2004

Transformers and Reactors

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1 Scope

This Standard prescribes the minimum mandatory requirements for the design and installation of transformers, reactors and instrument transformers. This document may not be attached to nor made a part of purchase order.

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 Materials System Specifications

14-SAMSS-531	*Power Transformers*
14-SAMSS-533	*Three-Phase Dry-Type Power Transformers*
14-SAMSS-534	*Overhead-Type Distribution Transformers*
14-SAMSS-536	*Pad-Mounted Three-Phase Distribution Transformers*

Saudi Aramco Engineering Standards

SAES-P-100	*Basic Power System Design Criteria*
SAES-P-114	*Power System and Equipment Protection*

SAES-P-113	*Motors and Generators*
SAES-P-116	*Switchgear and Control Equipment*

3.2 Industry Codes and Standards

American National Standards Institute

ANSI C2	*National Electrical Safety Code (NESC)*
ANSI C37.46	*Specification for Power Fuses and Fuse Disconnecting Switches*
ANSI C37.91	*Guide for Protective Relay Applications to Power Transformers*
ANSI C57.12.11	*Guide for Installation of Oil-Immersed Transformers*
ANSI C57.13	*Requirements for Instrument Transformers*
ANSI C57.16	*Requirements, Terminology and Test Code for Current Limiting Reactors*
ANSI C57.91	*IEEE Guide for Loading Mineral-Oil-Immersed Transformers*
ANSI C57.94	*Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General Purpose Distribution and Power Transformers*
ANSI/NFPA 70	*National Electrical Code (NEC)*
ANSI/IEEE 979	*Guide for Substation Fire Protection*

National Electrical Manufacturers Association

NEMA ST 1	*Specialty Transformers*

4 Definitions

Power Transformer: is equipment manufactured per 14-SAMSS-531.

Dry-Type Power Transformer: is equipment manufactured per 14-SAMSS-533.

Overhead-Type Distribution Transformer: is equipment manufactured per 14-SAMSS-534.

Pad-Mounted Distribution Transformer: is equipment manufactured per 14-SAMSS-536.

High Voltage (HV): Voltages 1000 V and greater. When used to describe transformer windings, can also be used as a relative term to differentiate the winding(s).

Low Voltage (LV): Voltages less than 1000 V. When used to describe transformer windings, can also be used as a relative term to differentiate the winding(s).

Instrument Transformer: is equipment manufactured per ANSI C57.13, unless specified otherwise in an individual SAMSS.

Current Transformer (CT): a type of Instrument Transformer.

Voltage Transformer (VT): a type of Instrument Transformer.

Control Transformer: is equipment manufactured per NEMA ST 1, unless specified otherwise in an individual SAMSS.

Current-Limiting Reactor: is equipment manufactured per ANSI C57.16.

SAMSS: Saudi Aramco Material System Specification

Approval: written approval of the Coordinator, Electrical Systems Division, Consulting Services Department, Saudi Aramco.

5 General

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

5.2 Unless indicated otherwise transformer ratings shown are non-forced cooled ratings at 65°C temperature rise.

5.3 **Power transformers** and **Distribution transformers** shall be the two-winding type. Normally, two-**winding power and distribution transformers** shall be delta-connected on the supply side and wye-connected on the load side.

Exception:

Other winding configurations may be specified with approval by the Electrical Standards Committee Chairman.

5.4 Transformers shall be provided with a HV tap changer for either deenergized operation or load tap operation. The type of tap changer shall be specified in the **SAMSS** Data Schedules.

5.4.1 Tap changers for deenergized operation shall have two (2) 2.5% above rated voltage and two (2) 2.5% below rated voltage taps.

5.4.2 Transformers with Load Tap Changers are utilized for voltage regulation. Load tap changers shall provide approximately ± 10% automatic adjustment of the low voltage winding voltage in approximately 5/8% steps with 16 steps above and 16 steps below rated voltage unless otherwise specified in the **SAMSS** Data Schedules.

5.5 All step-down transformers rated 10 MVA OA and above for residential or mixed commercial loads shall have a HV load tap changer with automatic voltage control.

5.6 The load tap changing requirements for step-down transformers that serve industrial type loads shall be determined by the project requirements and specified in the SAMSS Data Schedules.

5.7 Intertie transformers that may carry power flow in either direction shall be provided with a HV load tap changer.

5.8 All load tap changers shall be equipped for remote operation.

5.9 The manufacturer shall supply one uninscribed nameplate in addition to the ANSI standard nameplate. Saudi Aramco shall inscribe the site kVA, ampere, and voltage ratings on the blank nameplate.

5.10 Bids for **Power transformers** shall be evaluated in accordance with vendor instructions in 14-SAMSS-531 and the following:

Formula #1

$$C = P + (A * Li) + (B * Lc) = \$$$

Where

C = total evaluated present-value price used for bid comparison purposes including life cycle cost of losses;

P = transformer quoted price delivered to site;

A = cost/kW of no-load loss as stated on the SAMSS Data Schedules;

Li = guaranteed no-load loss at rated voltage, in kW;

B = cost/kW of load loss as stated on the SAMSS Data Schedules;

Lc = guaranteed load loss at the self-cooled rating, in kW, at referenced temperature.

The values of loss constants A and B shall be calculated by the following formulas and included in the **SAMSS** Data Schedules:

Formula #2

$$A = E1 * T1 * [(1 + i)^n – 1)] / [i * (1 + i)^n]$$

Formula #3

$$B = A * 0.49 \quad \$/kW$$

where

			Current Utilization Factors
E	=	Energy cost	$0.032/KWH
T1	=	number of hours per year transformer is energized	8766 HRS
i	=	interest rate or rate of return on investment	15%
n	=	number of years for capitalization of losses	20 YRS

Commentary Note:

The multiplier 0.49 is the load factor determined at 70% average load of the transformer by dividing the (average load)² by the (rated load)².

6 Sizing

6.1 Power and Distribution Transformers

6.1.1 Transformers shall be supplied with ANSI Standard preferred kVA Ratings at usual service conditions, unless specified otherwise on SAMSS Data Schedule-1.

6.1.2 The minimum OA self-cooled kVA rating of each OA/FA transformer shall be equal to the maximum operating load plus projected future load.

6.1.3 For transformers that are self-cooled only, a 10% load growth factor shall be added to the calculated load (maximum operating load plus projected future load).

6.1.4 The forced-cooled FA site rating of each transformer serving a double-ended substation shall be capable of feeding the entire operating load of both buses with the bus-tie breaker closed.

6.1.5 Forced-air cooling fans and controls shall be provided on all transformers rated 2500 kVA or larger. On transformers smaller than 2500 kVA, forced-air cooling is optional.

6.1.6 Two stages of forced cooling shall be allowed for transformers with OA ratings of 90 MVA or larger. The forced cooling may be forced-air (FA) and/or forced-oil-air (FOA).

6.1.7 The self-cooled kVA rating of power transformers shall be de-rated for continuous operation at higher than usual ambient temperatures in accordance with ANSI loading guides. The ambient temperatures in the Aramco operating areas are listed in SAES-P-100.

6.1.8 The derated kVA ratings shall satisfy the load requirements of paragraph 6.1.1 through paragraph 6.1.7. All attachments and accessories such as bushings, instrument transformers, and surge arresters shall be compatible with the site ambient temperatures and not limit the transformer kVA rating at site temperatures.

6.1.8 When transformers are operated in parallel, the total circulating current shall not exceed 10% of the rated current of the lowest kVA rated transformer.

Table 1 lists the maximum allowable percentage deratings for various site installations and transformer types and sizes. Manufacturers shall supply equipment that is designed to perform according to the ANSI loading guides.

Table 1 - kVA De-Rating Factors for Power and Regulating Transformers

	OIL-IMMERSED		DRY-TYPE			
	(65°C RISE)		LT 225 kVA		GE 225 kVA	
Transformer Location and Ambient Temp.	LT 225 kVA	GE 225 kVA	150°C	220°C	150°C	220°C
Outdoor Solar Exposed 45°C Avg, 55°C Max.	22.5%	15%	12%	8%	9%	6%
Outdoor Not-Exposed 40°C Avg, 50°C Max.	15%	15%	6%	4%	6%	4%
Indoor Well-Ventilated 40°C Avg, 45°C Max.	Not Allowed Indoors	Not Allowed Indoors	6%	4%	6%	4%
Indoor-Unmanned Air-Conditioned 35°C Avg, 45°C Max.	Not Allowed Indoors	Not Allowed Indoors	3%	2%	3%	2%
Indoor-Unmanned Air-Conditioned 30°C Avg, 40°C Max.	Not Allowed Indoors	Not Allowed Indoors	0%	0%	0%	0%

kVA Rating Symbols: LT = Less than; GE = Greater than or equal to.

6.2 Reactors

6.2.1 Current Limiting Reactors

6.2.1.1 Current Limiting Reactors utilized outdoor shall be copper wound, immersed in insulating oil in a steel tank. Derating shall be in accordance with the factors for Oil Immersed transformers in Table 1 above. The short time rating for fault limiting reactors shall be 3 seconds.

6.2.1.2 Current Limiting Reactors utilized indoor shall be copper wound air cooled and physically located to prevent electro-magnetic interference with surrounding objects and accidental contact from personnel. De-rating shall be in accordance with the factors for dry-type transformers in Table 1 above. The short time rating for fault limiting reactors shall be 3 seconds.

6.2.2 The short-time rating for motor starting reactors shall be sufficient to allow the maximum starting duty of the associated motor served.

6.3 Instrument and Control Transformers

Current transformers (CTs) used for revenue metering shall be ANSI accuracy Class 0.3.

7 Installation

7.1 General

7.1.1 The Field erection and testing of oil-immersed transformers rated 10 MVA or larger shall be in accordance with ANSI C57.12.11. The design of all transformer installations shall be in accordance with the NESC and NEC.

7.1.2 Dry-type transformers shall be installed in accordance with the NEC and ANSI C57.94.

7.1.3 Where the same disconnecting device feeds more than one transformer, a loadbreak disconnecting means shall be provided to permit de-energizing each transformer separately.

7.1.4 Separation of oil-filled power transformers from buildings and/or each other shall meet the minimum requirements of distance and/or fire barriers per ANSI/IEEE 979.

7.2 Instrument and Control Transformers

7.2.1 Fuses shall be provided on the high voltage (HV) primary side of all control or instrument transformers rated 34.5 kV and below.

7.2.2 CT's shall have a secondary rating of 5 amperes, except where another rating is required for compatibility with existing installations or for special applications.

7.2.3 CT ratios shall not be modified from the original manufacturer's design by multiple looping of the primary cables or secondary leads through the current transformer window.

7.2.4 CTs connected to time overcurrent relays shall have a protective relay accuracy class rating which will ensure that the CT does not saturate at the calculated fault level with the connected relays set on lowest tap. The CT ratio shall be chosen so that he secondary current will never exceed the short time rating of any relay or device connected in the secondary circuit.

7.2.5 CT secondary wiring shall not be spliced. Interconnection shall only be made at terminals of approved type.

8 Protection

8.1 General

8.1.1 This Section specifies the protection devices and schemes that shall be applied to power and distribution transformers installed in Saudi Aramco facilities.

8.1.2 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.

8.1.3 Refer to SAES-P-114 for general requirements of protection devices and schemes.

8.1.4 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.

8.2 Transformer Protection Schemes

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

8.2.1 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 2.

Table 2 - 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.

8.2.2 Generator Step-Up & 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 SAES-P-113.

8.2.3 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.

8.2.4 Intertie Autotransformer

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

8.2.5 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 8.4 to determine if fuse protection is allowed on the HV side of the distribution transformer in lieu of relays and a breaker.

8.2.6 Pole-Mounted Distribution Transformer

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

8.2.7 Grounding Transformer

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

1) 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.

2) 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 solidely grounded system the relay shall allow a pickup of 10% or less pf the transformer tating.

8.2.8 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:

1) 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:

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

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

2) 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.

8.2.9 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:

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

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

3) HV-side fuses, where allowed by Section 6.

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.

8.2.10 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.

8.2.11 HV Circuit Switcher

1) 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.

2) 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.

8.2.12 Transfer-Trip to Remote Breakers

1) 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.

2) 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.

8.3 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:

8.3.1 Differential Relays

1) General Requirements

a) 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.

b) 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.

c) 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.

d) 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.

2) Current Transformers for Differential Relays

a) 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.

b) 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.

8.3.2 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.

8.3.3 Ground Overcurrent Relays

1. General Requirements

a) 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.

b) 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.

c) 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.

2. Ground Sensors & Window-Type CT's

a) 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.

b) 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.

3. Neutral Overcurrent Relays

a. 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.

b. 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.

c. 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.

d. 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.

4. 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.

8.3.4 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.

8.3.5 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.

8.3.6 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.

8.3.7 Overtemperature Devices (Device 49T)

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

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

8.3.8 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.

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

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

2. 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.

3. Trip-isolation test switches shall be installed in the trip circuits from the 86T lockout relays. See Section 4 for details of the test switches.

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

8.4 Fuse Protection of Transformers

8.4.1 General Requirements

1. 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.

2. 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.

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

4. Individual transformers of banked transformers shall not be protected by fuses.

5. 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.

6. 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.

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

8.4.2 Fuse Ratings

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

2. 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.

3. 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.

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

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

6. 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.

8.4.3 Installation Requirements

1. 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.

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

8.4.4 Fuse Coordination

1. 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.

2. 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.

Revision Summary

30 November, 2003	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with no other changes.
28 January, 2004	Minor revision.
31 July, 2004	Minor revision.