Engineering Standard

SAES-P-121 4 June 2013

Transformers and Reactors

Document Responsibility: Electrical Substations Equipment Stds Committee

Saudi Aramco DeskTop Standards

Table of Contents

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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.

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

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.

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 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*
16-SAMSS-504	*Indoor Metal-Clad Switchgear: 1 to 38 kV*

Saudi Aramco Engineering Standards

SAES-P-100	*Basic Power System Design Criteria*
SAES-P-104	*Wiring Methods and Materials*
SAES-P-113	*Motors and Generators*
SAES-P-114	*Power System and Equipment Protection*
SAES-P-116	*Switchgear and Control Equipment*
SAES-P-119	*Onshore Substations*

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)*
IEEE C57.116	*Guide for Transformers Directly Connected to Generators*

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 Materials System Specification

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

Site Rating: Actual operating rating of the equipment based upon de-rating factor in Table 1 of this standard.

ONAN: Oil Natural-Air Natural

ONAF: Oil Natural-Air Force

OFAF: Oil Force-Air Force

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.

Exceptions:

1. Other winding angular displacement between high-voltage and low-voltage terminal voltages may be specified with approval by the Electrical Substations Equipment Standards Committee Chairman.

2. Generator Step up transformer shall be delta-connected on the generator (low voltage) side and wye-connected on the transmission (high voltage) side.

5.4 Three winding transformer shall not be used.

Exception to 5.4:

*If **approval** is obtained.*

5.5 The load tap changing requirements for step-down transformers shall be determined by the project requirements and specified in the SAMSS Data Schedules.

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

5.7 When specified all load tap changers shall be equipped for remote operation.

5.8 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 → $B = A * 0.49$ $/kW

			Current Utilization Factors
Where:			
E	=	the energy cost must be obtained from Facilities Planning Department	
T1	=	number of hours per year transformer is energized	8766 HRS
i	=	interest rate or rate of return on investment	5.9%
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.

5.9 Dry-Type Transformers

Transformers shall have the following characteristics:

a) Windings and all **main circuit conductor**s shall be copper.

b) Windings shall be encapsulated with solid insulation or vacuum pressure impregnated.

c) Shall fully comply with either of the following:

i) IEC 60726

ii) UL listed which requires the transformer be manufactured in accordance with applicable NEMA, ANSI, UL and IEEE standards.

d) Enclosure material and protection are listed in SAES-P-104.

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 ONAN self-cooled kVA rating of each ONAN/ONAF transformer shall be equal to the maximum operating load plus projected future load. The projected future load shall be defined as per project DBSP requirement.

6.1.3 Captive transformers shall be limited to motors rated 7500 HP and larger. Captive transformers rating shall be selected by the motor vendor.

6.1.4 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).

6.1.5 The forced-cooled ONAF 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.

6.1.6 Forced-air cooling fans and controls shall be provided on all transformers rated 2500 kVA or larger, and shall not be supplied on transformers rated less than 2500 kVA

6.1.7 For transformers with ONAN ratings of 90 MVA or larger two stages of forced cooling are acceptable. The forced cooling may be forced-air ONAF and/or forced-oil-air (OFAF). Two stages of cooling shall not be supplied on transformers less than 90 MVA.

6.1.8 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 Saudi Aramco operating areas are listed in SAES-P-100.

6.1.9 The derated kVA ratings shall satisfy the load requirements of paragraph 6.1.1 through paragraph 6.1.8. 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.

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

6.1.11 The maximum allowable percentage deratings for various site installations and transformer types and sizes shall be in accordance with Table 1 below. 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, non-air-conditioned, well-Ventilated 40°C Avg, 45°C Max.	Not Allowed Indoors	Not Allowed Indoors	6%	4%	6%	4%
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.

6.1.12 The Generator Step-Up (GSU) transformer selection and application shall be in accordance with IEEE 57.116 guidelines and the following:

a) Shall be sized to carry the maximum generator output establish by the capability curves and site conditions for all possible tap positions.

b) GSU MVA rating shall never limit the generator MW output for any expected turbine output.

c) Shall be capable of absorbing without damage an energy amount equal in value and time to the energy dissipated in a fault at the generator terminals.

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 Fire protection and separation of oil-filled power transformers from buildings and/or each other shall meet the minimum requirements indicated within SAES-P-119.

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 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 the secondary current will never exceed the short time rating of any relay or device connected in the secondary circuit.

7.2.3 CT secondary wiring shall not be spliced.

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

8.1.3 Where "DD-950114/X" is mentioned, this is a Saudi Aramco Library Drawing. The "X" designates the sheet number. These drawings present typical useful information. 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 2 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 surge arrestor and 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) Grounding transformers shall be protected by phase overcurrent relays through a set of devices 50/51XT phase overcurrent relays that 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 solidly grounded system the relay shall allow a pickup of 10% or less of the transformer rating.

8.2.8 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.

8.2.9 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 high 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.

8.2.10 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.

8.2.11 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. Direct wired transfer trips shall be via a self reset tripping function relay which shall have a target to indicate the source of the trip.

2) Where the power transformer is protected by remote relays a hand-reset tripping and lockout function located at the remote control and protection panel of the high side shall also transfer-trip local incomer circuit breakers at the low side of the transformer via a self reset tripping function which shall have a target to indicate the source of the trip.

3) The transfer-trip signal 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.

4) On the low side of the transformer an inter-locking scheme shall be provided to prevent closing low side breaker while the high side breaker is in open condition.

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 unless it can be filtered by the

transformer differential relay. 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 only 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.

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 (Adjustable pickup)

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 ANSI/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 only 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 only 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.

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 provide sensitive protection but maintaining the maximum current complying with the relay ratings (typically 50:5 or 50:1 CT's are recommended based on the used relay rating).

b) Where a single window-type CT cannot be fitted to cover the three phases of one conductor per phase circuit, a ground overcurrent relay (Device 50/51G) shall be connected residually 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 and feeding double-ended switchgear, in accordance to 16-SAMSS-504, 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.

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.

8.3.4 Directional Phase and Ground Overcurrent Relays (Device 67L/67TG)

Directional phase and ground overcurrent relays (Device 67L/67TG) with instantaneous and time overcurrent units shall be installed on the

LV side of transformer connected to buses with normally-closed bus ties or other normal LV sources. The Device 67L/67TG 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 Mechanical Protection and Indication

For transformers equipped with transformer differential protection, all mechanical trip and alarm points shall be connected to either the transformer overcurrent or the differential protection relay as digital inputs. Trip signals include sudden pressure (63) operations in the main and tap changer tanks if provided and low oil level signal (71) if such function is not provided by 63. Other signals such as winding and top oil temperature (26) shall alarm via the relay to the substation automation system. The Mechanical protection shall have separate trip signal from the differential protection.

For transformers that are protected by overcurrent relays only, the mechanical alarms shall be connected to digital controller which in turn trip or alarms as required by the above.

8.3.7 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 ONAN 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 ONAN 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. 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 sub-transient 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

4 June 2013 Major revision.