

IEEE Guide for Transformers Directly Connected to Generators

Sponsor

**Transformers Committee
of the
IEEE Power Engineering Society**

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Foreword

(This Foreword is not a part of IEEE C57.116–1989, IEEE Guide for Transformers Directly Connected to Generators.)

ANSI/IEEE C57.12.00–1987, IEEE Standard General Requirements for Liquid Immersed Distribution, Power, and Regulating Transformers, and other related C57 series standards provide guidance to users regarding transformer application, design, connections, performance characteristics, testing etc. However, transformers, directly connected to generators experience excitation and short-circuit duties beyond those covered in the C57 series. Therefore, in 1979, the IEEE Transformers Committee decided that an application guide for such transformers was needed by the industry. Accordingly, a working group was formed and a guide prepared. This guide describes the selection, application, and specification considerations for the unit and unit auxiliaries transformers, taking into account their connections, voltage and kilovoltampere ratings, and excitation and through-fault capabilities during possible operating conditions, both normal and abnormal. Also included are load-tap changing and isolated phase bus-duct heating considering This guide does not address phasing procedures, basic impulse level selection, or loading practices.

This guide is based on the latest knowledge, design, and application experience of the industry. It is intended to provide guidance to application and specification engineers and therefore its use is strictly voluntary. Its use may become mandatory only when required by a duly constituted legal authority or when specified in a contractual relationship.

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IEEE Guide for Transformers Directly Connected to Generators

1. Scope and References

1.1 Scope

This guide describes selection and application considerations for the unit transformer and unit auxiliaries transformer. Consideration is given to connections that include direct connection and connections through generator breakers and load break switches. The considerations referred to in this guide apply to hydroelectric and thermal electric generating stations. Various transformer connections and possible operating problems under normal and abnormal conditions are treated.

Phasing procedures, basic impulse insulation level selection, and loading practices are not covered.

1.2 References

This guide shall be used in conjunction with the following publications:

- [1] ANSI C50.13-1977, American National Standard Requirements for Cylindrical Rotor Synchronous Generators.¹
- [2] ANSI C57.12.30-1977, American National Standard Load-Tap-Changing Transformers 230 000 Volts and Below 3750/4687 Through 60 000/80 000/100 000 kVA, Three Phase.
- [3] ANSI C57.12.70-1978 (R1987), American National Standard Terminal Markings and Connections for Distribution and Power Transformers.
- [4] ANSI C84.1-1982, American National Standard Voltage Ratings for Electric Power Systems and Equipment.
- [5] ANSI C92.2-1987, American National Standard Power Systems —Alternating-Current Electrical Systems and Equipment Operating at Voltages above 230 Kilovolts Nominal—Preferred Voltage Ratings.
- [6] ANSI/IEEE Std 100-1988 IEEE Standard Dictionary of Electrical and Electronics Terms.²
- [7] ANSI/IEEE Std 505-1977 IEEE Standard Nomenclature for Generating Station Electric Power Systems.
- [8] ANSI/IEEE C57.12.00-1987 IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

²ANSI/IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08854-4150 or from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

2. Definitions

The definitions listed below are in accordance with ANSI/IEEE Std 100-1988 [6]³ and ANSI/IEEE Std 505-1977 [7].

generator (rotating machinery): A machine that converts mechanical power into electrical power.

station service transformer (SST): A transformer that supplies power from a station high-voltage bus to the station auxiliaries and also to the unit auxiliaries during unit startup and shutdown or when the unit auxiliaries transformer is not available or both.

unit: The generator or generators, associated prime mover or movers, auxiliaries, and energy supply or supplies that are normally operated together as a single source of electric power.

unit auxiliaries transformer (UAT): A transformer intended primarily to supply all or a portion of the unit auxiliaries.

unit transformer (UT): A power system supply transformer that transforms all or a portion of the unit power from the unit to the power system voltage.

3. Introduction

The unit-connected generating system came into usage as generator size and generator bus fault current levels began to exceed the capability of breakers that were available to isolate the generator from the power system. Generally, the generator auxiliaries load is fed from a transformer that is connected directly to the generator bus. An alternate source of power is normally supplied from the transmission system by a second transformer during unit startup, shutdown, and other contingencies. Such a system is shown in Fig 1. Typically, an isolated phase bus is used for connection between the generator and its UT and UAT; thus, the system is unit connected.

Studies indicate that through faults for the UT are normally not severe in terms of either thermal or mechanical duty. However, the stresses in the UAT can be severe under certain conditions, such as low-side faults, paralleling out of phase with the SST, and generator load rejection.

On units without generator breakers, faults at location (3) in Fig 1 will be fed predominantly by two sources, namely, through the UT from the system and from the generator. Normally the differential relay protection system, which will detect faults at location (3), will initiate a unit trip that will disconnect the unit from the system and remove the generator excitation. The loss of load may result in a higher voltage on the generator that will continue to feed the fault. This higher voltage due to load rejection will increase the generator's current contribution to a level higher than before load rejection. However, the system contribution will be absent. The generator's contribution will continue at a level and for a period that depends on the generator's fault-current decrement characteristics. The fault-current decrement characteristics are a function of the generator short-circuit parameters and its excitation system. As a result of the generator's fault-current decrement characteristics, faults at location (3) in Fig 1 may exceed the thermal and mechanical capabilities of the UAT if it is designed solely in accordance with ANSI/IEEE C57.12.00-1987 [8].

Abnormal operating conditions, such as generator load rejection, may result in high-generator bus voltages that may also cause overexcitation of the transformers connected to the generator bus. Should a fault occur at location (3) in Fig 1 during this period of overexcitation, both the thermal and mechanical capability of the UAT may be exceeded.

Out-of-phase paralleling of the UAT with the SST can produce high currents that may exceed the mechanical capability of these transformers. Frequency mismatch between the generator and system voltages also can cause severe mechanical stresses on the transformers.

³ The numbers in brackets correspond to those of the references in 1.2.

A generator breaker at location (2) in Fig 1 would not completely eliminate all of the system problems described in the preceding paragraphs. Generally, it can be shown that thermal and longtime overexcitation exposures of the UAT can be eliminated by the use of a generator breaker, but the mechanical aspects of paralleling two sources out-of-phase or of frequency mismatch must still be given consideration in the design of the UAT.

The following is a list of other considerations that should be evaluated in the selection and application of UTs and UATs.

- 1) Cooling requirements
- 2) Single-phase versus three-phase transformers for UT applications
- 3) UTs with single high-voltage winding and split low-voltage windings
- 4) Overall economic evaluation of equipment costs, installation costs, and the cost of losses

Due to limited scope, these other considerations are not discussed in this guide. However, they should be considered in the selection of transformer parameters.

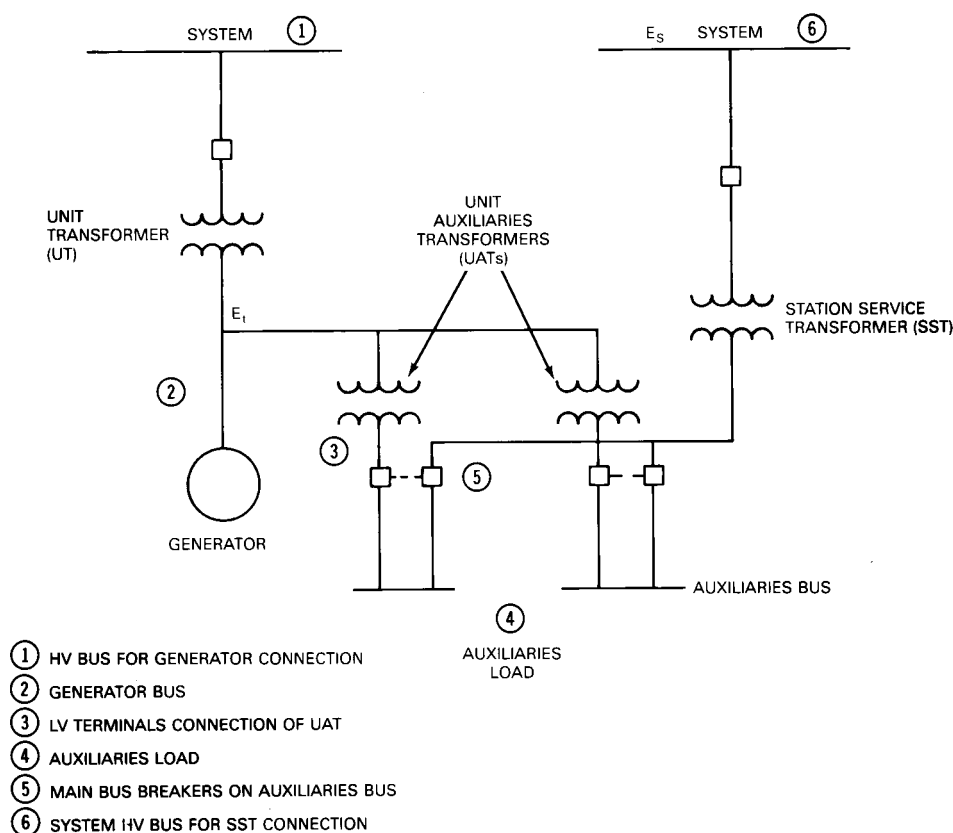


Figure 1— Typical Generating Station Auxiliaries Power System One-Line Diagram

4. Transformer Connections

4.1 Unit Transformer Connections

The most common connections used for large UTs are shown in Fig 2. For voltages above 115 kV where the neutral is normally solidly grounded, the high-voltage wye connection is advantageous due to the economics of reduced neutral dielectric insulation.

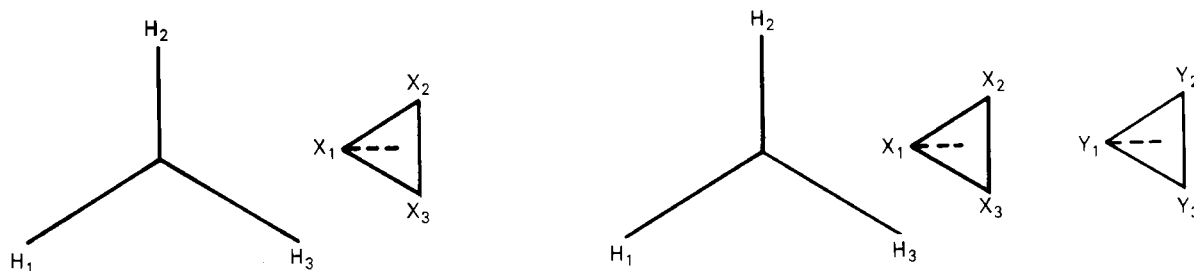


Figure 2— Typical Unit Transformer Connections

4.2 Unit Auxiliaries Transformer Connections

The most common connections used are shown in Fig 3.

The delta connection on the high-voltage side allows the proper phase angle around the system loop.

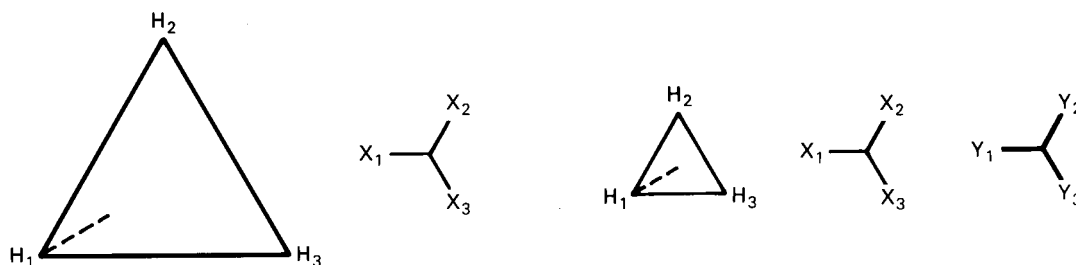


Figure 3— Typical Unit Auxiliaries Transformer Connections

4.3 Unit Transformer and Unit Auxiliaries Transformer External Connections

In Fig 1, usually the unit auxiliaries bus and the system bus are required to be in phase for bus transfer considerations. Proper phasing can be obtained by using the connections shown in Figs 2 and 3 for the UT and the UAT respectively. Assuming a standard delta-wye UT (Fig 2) and a phase-voltage sequence of A, B, C on the low side connecting A to X_1 , B to X_2 , C to X_3 and A' to H_1 , B' to H_2 , and C' to H_3 will result in a phase displacement of 30° with the high side leading the low side. With the same phase-voltage sequence and now A connected to X_3 , B to X_2 , C to X_1 and A' to H_3 , B' to H_2 , C' to H_1 , the resulting phase displacement will still be 30° , but now the low side will lead the high side by 30° . The corresponding would be true for the UAT.

For further information on this subject, see ANSI/IEEE C57.12.70-1978 (R1987) [3].