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IEEE Guide for Protective Relaying of Utility-Consumer Interconnections

Sponsor

**IEEE Power System Relaying Committee
of the
Power Engineering Society**

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Abstract: IEEE C37.95-1989, *IEEE Guide for Protective Relaying of Utility-Consumer Interconnections*, is intended to cover applications involving service to a consumer that normally requires a transformation between the utility's supply voltage and the consumer's utilization voltage. Interconnections supplied at the ultimate utilization voltage are not covered.

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Foreword

(This Foreword is not a part of IEEE C37.95-1989, IEEE Guide for Protective Relaying of Utility-Consumer Interconnections.)

The principle value of this guide will be realized if it establishes a common ground of understanding among all of those involved in the process of supplying electric power from the utility to the consumer.

This guide was prepared by the Consumer-Utility Working Group of the Consumer Relaying Coordination Subcommittee of the IEEE Power System Relaying Committee. At the time this guide was approved, the Working Group membership was as follows:

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IEEE Guide for Protective Relaying of Utility-Consumer Interconnections

1. Introduction

The physical means by which electric energy is received from the electric utility is known as an interconnection tie. The primary elements include transmission or distribution circuits, transformers, and switching devices in the form of circuit breakers, fuses, and isolating disconnect switches. The secondary elements include sensing devices to obtain information to operate the primary equipment intelligently, and protective relays to initiate removal of equipment from service automatically and quickly when an electric fault or disturbance occurs.

It is important to remember that the physical laws of nature which govern the operating behavior of an electric power system do not recognize defined lines of electric facility ownership. Thus, for a well-engineered interconnection, it is suggested that problems in electric power system protection be studied and analyzed critically without regard to ownership.

From the viewpoint of service reliability and service continuity, it is basic to understand that the best conceived, best implemented protective relaying system is no substitute for an adequately designed power system. Indeed, inadequately applied protective relaying will contribute to inadequate and unsatisfactory performance of an otherwise well-designed power system. In considering a new installation, or changes to an existing arrangement, it is very important that protective relaying and safety be given careful attention in the early stages of planning.

2. Scope

This guide contains information on a number of different protective relaying practices for the utility-consumer interconnection. It is intended to cover applications involving service to a consumer that normally requires a transformation between the utility's supply voltage and the consumer's utilization voltage. Interconnections supplied at the ultimate utilization voltage are not covered.

This guide is not intended to supplant specific utility or consumer practices, procedures, or requirements, or any contractual agreement between the utility and consumer. The examples in Section 9 are used for illustrative purposes only and do not necessarily represent the preferred protection trader all conditions.

This guide addresses users (consumers), with or without generation, that are connected to utility subtransmission or transmission circuits. The specific control schemes associated with generation are not addressed. It is not intended to apply necessarily to consumer generation connected to utility distribution circuits.

3. Purpose

The primary purpose of this guide is to help those who are responsible for the application of protective relaying for the electrical interconnection between utility and consumer systems. It is anticipated that it will be used by representatives of the utility, the consumer, and their consultants who are responsible for the specification, design, and operation of the interconnection. Recognizing the diverse audience being addressed, background information and references are included in Section 4 to direct the reader to more complete treatment of the material.

4. References

- [1] ANSI C2-1990, National Electrical Safety Code.¹
- [2] ANSI/IEEE C37.010-1979 (R1988), Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.²
- [3] ANSI/IEEE C37.2-1987, Standard Electrical Power System Device Function Numbers.
- [4] ANSI/IEEE C37.5-1979, Guide for Calculation of Fault Current for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis.
- [5] ANSI/IEEE C37.90-1978 (R1982), Relays and Relay Systems Associated with Electric Power Apparatus.
- [6] ANSI/IEEE C37.91-1985, Guide for Protective Relay Applications to Power Transformers.
- [7] ANSI/IEEE C37.93-1987, Guide for Power System Protective Relay Applications of Audio Tones over Telephone Channels.
- [8] ANSI/IEEE C37.96-1988, Guide for AC Motor Protection.
- [9] ANSI/IEEE C37.97-1979 (R1984), Guide for Protective Relay Applications to Power System Buses.
- [10] ANSI/IEEE C37.99-1980 (R1985), Guide for Protection of Shunt Capacitor Banks.
- [11] ANSI/IEEE C37.101-1985, Guide for Generator Ground Protection.
- [12] ANSI/IEEE C57.13-1978 (R1986), Standard Requirements for Instrument Transformers.
- [13] ANSI/IEEE Std 141-1986, Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).
- [14] ANSI/IEEE Std 241-1983, Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book).

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²ANSI/IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, or from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

- [15] ANSI/IEEE Std 242-1986, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).
- [16] ANSI/IEEE Std 315-1975 (R1989), Graphic Symbols for Electrical and Electronics Diagrams.
- [17] ANSI/IEEE Std 446-1987, Recommended Practice for Emergency and Standby Power for Industrial and Commercial Applications (IEEE Orange Book).
- [18] ANSI/IEEE Std 493-1980, Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book).
- [19] ANSI/IEEE Std 519-1981, Guide for Harmonic Control and Reactive Compensation of Static Power Converters.
- [20] ANSI/NFPA 70-1987, National Electrical Code.³
- [21] IEEE Std 80-1986, Guide for Safety in AC Substation Grounding.⁴

5. Establishing Consumer Service Requirements and Supply Methods

5.1 Interconnection

The utility-consumer interconnection provides the path for power flow between supplier (utility) and user (consumer). The interconnection may comprise one or more circuits and is assumed to include voltage transformation. For the purposes of this guide, the extent of the interconnection is defined to include the nearest source-side protective device for transformer high-side switching and the transformer low-side bus and switching devices.

5.2 General Process

The supply that is selected should satisfy the consumer's load requirements. Available utility supply options in the area as well as the utility's design standards and operating and maintenance practices should also be considered.

5.2.1 Consumer Defines Requirements

Prior to meeting with utility personnel, the consumer should define his present and future load requirements. He should establish the connected kVA along with the average and peak demand and reactive power requirements, the effect of interruptions and voltage dips on plant operation, the required dependability and security of the utility's electrical service, plus any other needs that may be unique to the operation. The consumer's engineer should be prepared to discuss these requirements in detail with utility engineers to ensure that there is a clear understanding of the consumer's requirements.

5.2.2 Utility Defines Service Availability

The utility should describe the supply voltages available in the area and estimate the initial and total costs of the various alternatives. Most utilities establish nominal limits on the kVA that can be supplied at different voltage levels. The availability of single- and multiple-line supply and the performance level of each should be discussed in detail. In addition, the utility should inform the consumer of any required studies, unusual problems, or future plans that may

³NFPA documents are published by the National Fire Protection Association, Publications Sales Division, Batterymarch Park, MA 02269. Copies are also available from the Sales Department of the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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affect the quality or continuity of supplying service. Some utilities publish standard information booklets detailing the requirements for service.

When the consumer has identified critical power requirements, the utility engineer should investigate their characteristics to be certain that both parties have a clear understanding of the effect of interruptions and voltage dips. The utility may then be able to suggest a supply system that will meet these requirements, or suggest plant control changes to make the operation more successful. It should be recognized that there is no electrical utility supply method that completely eliminates the possibility of momentary service interruptions or voltage dips. If the consumer cannot tolerate these service disruptions, consideration should be given to the installation of specific facilities to allow riding through these periods.

The primary cause of service complaints is the failure to adequately evaluate the effect of interruptions and voltage dips on the consumer's equipment. Depending on the type of operation, a voltage dip of only a few cycles can be very costly because it can disrupt an industrial process. It is especially critical that a careful evaluation be made by the consumer of the voltage requirements of his loads and the electronic systems that provide process control. In many instances, special means are available to make the loads tolerant of unavoidable voltage conditions on the power system.

5.3 Information Exchange

Once the supply method is established, a further exchange of information is required so that the station design can be completed and the utility can make the necessary preparations to supply the service. By establishing good communication between the utility and the consumer as early as possible for either a new or modified supply, specific requirements can be identified and included in the initial design before equipment is ordered.

5.3.1 Typical Information Furnished by Utility

- Available short-circuit current—range of single- and three-phase to ground-fault current and associated X/R ratios at the consumer's point of service. Values for normal and alternate supply facilities as well as any anticipated future values should be provided.
- Expected minimum, maximum, and nominal voltage at the consumer's point of service for available voltage levels.
- Outage history of the supply—both forced and maintenance outages
- Estimated frequency, duration, and magnitude of momentary voltage dips at the consumer's point of service
- Operating requirements and restraints
- Specific protection requirements to coordinate with the utility system
- Specific reclosing practices on both normal and alternate supply facilities
- Harmonic content, voltage fluctuation, and current unbalance constraints imposed by the utility. Also quantification of voltage waveform distortion and harmonic current injection from other sources on the utility system if requested by the consumer
- Additional information requested by the consumer, such as:
 - Supply line construction and routing
 - Supply substation arrangement and location
 - Utility grounding and lightning protection practices
 - Metering arrangements and data

5.3.2 Typical Information Furnished by Consumer

- Expected service date (when consumer will be ready for power)
- Complete one-line diagram of plant distribution system
- Preferred supply voltage
- Transformer ratings, connections, voltage taps, and impedances
- Power factor correction capacitor ratings and connections

- Switchgear specifications, including protective relay types and ranges
- Motor loads, types, sizes, and starting frequency
- Unusual load characteristics, such as those due to furnaces, thyristors, and other nonlinear loads (include flicker and harmonic producing equipment)
- Generation information, including short-circuit information
- Voltage balance requirements
- Protection and control schematic drawings, as appropriate
- Point of interconnection physical arrangement drawings
- Expansion plans, which include projected loads, future substation development, and estimated dates
- Station ground grid design
- Maintenance capability of consumer personnel

5.3.3 Future Utility System Changes

The utility should inform the consumer of any substantial utility system changes. For example, the installation of a large transformer that alters short-circuit currents at the supply point may affect the consumer's power system. In like manner, changes in regulator or capacitor location may also affect the consumer's power system.

5.4 Specific Supply Considerations

In determining the final supply method, consideration should be given to the design of the interconnection, the arrangement of the utility's supply system, its protective relaying requirements, and its maintenance requirements and responsibilities.

5.4.1 Division of Ownership

Individual operating and maintenance philosophies of the consumer and utility may impact electric system design. Proper engineering design should not be compromised. This guide places primary emphasis on principles and practices to be applied toward coordinated operation of an integrated system.

5.4.2 Nature of Interconnection

The utility-consumer interconnection tie may consist of one circuit or multiple circuits. Single service consists of a single line supplied from a single source and connected to a single transformer, with connections to the consumer's distribution system at the low-voltage side of the transformer. Such service is subject to interruption on forced or planned outage of the supply source, line, or transformer. If single line supply is not adequate, alternative supply facilities, such as a standby supply or multiple-line supply with or without multiple transformation, should be considered. A normally open standby supply from a second utility source can enable restoration of service by automatic or manual switching operations on failure of the principal single-line supply. Multiple, full-capacity interconnection lines routed over separate rights of way, with multiple transformation, will enhance continuity of service. Ideally, multiple lines should not originate at the same bus, since an outage of that bus would result in a consumer outage. Utility supply configurations, which provide two interconnection lines include:

- Two lines from separate utility sources
- Two lines derived by sectionalizing an existing utility tie line

Multiple supply lines may terminate at the consumer substation if a strong source is required to serve the consumer's load or other area loads.

As described in succeeding sections of this guide, the effects on service voltage of local and remote utility supply system faults will depend on the nature of the interconnection. Supply configurations are covered in more detail in Section 6

5.4.3 Interconnection Protection Requirements

The complexity of the protection used at an interconnection will vary depending upon voltage level, system configuration, the type and amount of consumer load, and specific requirements of either the consumer or utility. In a dual supply system, for example, additional relaying may be required to respond to undesirable power flow from one supply to the other. Special consideration must be given to consumers with large motors or generators connected to their system.

If a bus is installed at the consumer's location as part of the utility supply, the protective relaying for the supply lines and bus will normally be considered as part of the utility system. The consumer should be familiar with the effects of the protection applied to these facilities, since the duration of interruptions or voltage dips due to faults on the supply lines or buses has a direct effect on service.

Regardless of ownership, the protective equipment should be specified and designed to provide a coordinated system. If the consumer's facilities become an integral part of the utility system, protection requirements should assure the integrity of the supply system. This may result in some apparent duplication of protective equipment based on the philosophy and objectives of the utility and consumer in regard to protection. The protection of the utility-consumer interconnection facilities should satisfy the objectives of both parties. In all cases, the protection requirements, relay or fuse specification, relay setting or fuse size, and testing procedures should be discussed and agreed upon by both parties.

5.4.4 Maintenance

In determining the interconnection system and the associated protective equipment, it should be recognized that periodic maintenance of all facilities is required. Comprehensive maintenance includes operational testing of relays, control batteries, and interrupting devices. This applies to the utility supply system as well as the consumer's utilization system. During periods of maintenance, the reliability of the supply or possibly even the continuity of service may be affected. This work should be coordinated between the utility and consumer so as to minimize any adverse impact. If the consumer cannot tolerate the loss of service for periodic maintenance, the installation of an alternate supply will be required.

5.5 Load Considerations

The primary concern in applying protection for faults on the electrical supply or utilization systems is to minimize personnel hazard and equipment damage. However, the effect of the protective equipment on the load served should be considered. The operating time of fuses or protective relays and switching devices determines the time to isolate a faulted piece of equipment. During the fault, the electric system is subjected to abnormal currents and voltages. Abnormal voltages on unfaulted portions of the system can affect the operation of process controls, ac contactors, motors, computers, and other electronic devices. Reclosing practices of the utility can provide restoration of service to all facilities for a temporary fault, such as lightning-induced flashover of an overhead line. Reclosing can provide automatic restoration of service to a portion of the system once a permanently faulted section has been isolated. The consequences of reclosing vary and can be significant if the consumer's system includes generators or large motors. It is essential that the implications be understood and that designs be selected to meet the required objectives.

5.6 Other Supply Considerations

Harmonics, grounding, ferroresonance, and voltage regulation are discussed briefly in this section. Personnel responsible for the protection of the interconnection should recognize that these conditions can affect the quality of service and possibly even the performance of protective relays and their associated control circuits.