



IEEE Guide for Reliability-Based Placement of Overhead and Underground Switching and Overcurrent Protection Equipment up to and Including 38 kV

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

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STANDARDS

IEEE Guide for Reliability-Based Placement of Overhead and Underground Switching and Overcurrent Protection Equipment up to and Including 38 kV

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Abstract: Analytical techniques to assist in the placement of switching and overcurrent protection devices on distribution feeders for reliability purposes is provided in this guide.

Keywords: device placement, distribution, IEEE 1806™, interruptions, overhead, protection, reliability, sectionalizing, switching, underground

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Introduction

This introduction is not part of IEEE Std 1806-2021, IEEE Guide for Reliability-Based Placement of Overhead and Underground Switching and Overcurrent Protection Equipment up to and Including 38 kV.

This is a new guide developed to provide means and methodologies for proper placement of switches and protective devices to achieve the desired performance characteristics and reliability for distribution feeders, including feeder and branch line equipment, with operating voltages up to and including 38 kV. Drivers for device placement, such as reliability and operational considerations, are identified. Various types of switching and overcurrent equipment are covered such as: manual switches, automated switches, reclosers, sectionalizers, and fuses. Impacts on reliability and device placement are addressed for factors such as fault rate, interruption duration, exposure length (e.g., km or miles), customers affected, and distribution automation and automated restoration. Examples are also provided in [Annex A](#).

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IEEE Guide for Reliability-Based Placement of Overhead and Underground Switching and Overcurrent Protection Equipment up to and Including 38 kV

1. Overview

1.1 Scope

This guide provides analytical techniques to assist in the placement of switching and overcurrent protection devices on distribution circuits for reliability purposes.

1.2 Purpose

This guide provides means and methodologies for proper placement of switches and protective devices to achieve the desired performance characteristics and reliability for distribution circuits, including feeder and branch line equipment, with operating voltages up to and including 38 kV. Drivers for device placement, such as reliability and operational considerations are identified. Various types of switching and overcurrent equipment are covered such as: manual switches, automated switches, reclosers, sectionalizers, and fuses. Impacts on reliability and device placement are addressed for factors such as fault rate, interruption duration, exposure length (e.g., km or miles), customers affected and distribution automation and automated restoration.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{1,2}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

¹The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

²The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1366™, IEEE Guide for Electric Power Distribution Reliability Indices.^{3,4}

IEEE Std 1782™, IEEE Guide for Collecting, Categorizing, and Utilizing Information Related to Electric Power Distribution Interruption Events.

IEEE Std 1854™, IEEE Trial-Use Guide for Smart Distribution Applications.

IEEE Std C37.230™, IEEE Guide for Protective Relay Applications to Distribution Lines.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁵

customer exposure ratio (CER): A proportion of the actual load exposure to the maximum load exposure for customers on a particular circuit.

distribution automation: A technique used to limit the outage duration and restore service to customers through fault location identification and automatic switching.

feeder: Refers to any medium-voltage distribution circuit, possibly including low-voltage secondary circuits. It need not be radially configured.

interrupting device: A switching device used to stop the flow of power. Examples include circuit breakers, line reclosers, line fuses, disconnect switches, sectionalizers, and/or others.

load exposure (LE): A measure of the average interruption exposure for customers on a particular circuit.

main line: The part of a feeder or circuit that is, typically, fed directly from a source substation breaker (or other substation protective device), that normally serves significant customer load, and/or normally has significant tie capability to another circuit.

overcurrent protective device (OCPD): A fuse or circuit breaker.

sectionalization: Placement of overcurrent protective devices and/or switching equipment at various locations on distribution feeders to limit the number of customers exposed to sustained outages.

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⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

⁵*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

3.2 Acronyms and abbreviations

CAIDI	customer average interruption duration index
CELID	customers experiencing long interruption durations
CEMI	customers experiencing multiple interruptions
CI	customer interruptions
CMI	customer minutes of interruption
DA	distribution automation
FDIR	fault detection, isolation, and restoration
FLISR	fault location, isolation, and service restoration
MAIFI	momentary average interruption frequency index
MAIFLe	momentary average interruption event frequency index
OCPD	overcurrent protective devices
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index

4. Distribution system protection philosophy

There are primarily three guiding principles of distribution system protection as follows:

- a) Reduce the danger caused by electrical faults to the public and employees.
- b) Reduce the effect of electrical faults on customers.
- c) Reduce electrical fault damage to company equipment and assets.

This guide is focused on the second listed principle [item b)]. In some cases, there is no electrical fault, but there is a loss of electrical supply, such as when a connection corrodes and burns open. In these cases, the combined scheme of protection and automated service restoration may operate. As an example of an application involving a fault that is out of scope, consider the situation where a line recloser is installed at a point where downstream faults would not provide enough current to trip an upstream breaker or recloser. In this case, the reasons for installing the recloser are more related to reducing the danger caused by electrical faults to the public and damage to company equipment.

The methods shown in this guide calculate the reliability benefits of placement of overcurrent protective devices (OCPD) and other switching devices based on mitigating the effect of sustained faults and other breaks in electrical continuity on customers. For this guide, this reliability improvement is defined as a reduction in interruption frequency, interruption duration, or any combination.

There are other reasons to install a line recloser, not covered by this guide. For a more complete discussion of the application and coordination of protection for radial power-system distribution lines, see IEEE Std C37.230^{TM,6}.

Note that all costs, estimates, and calculations provided in this guide are intended for illustrative purposes only, and do not reflect specific applications. Costs also vary based on location, timing, and other market factors, and these estimates should not be relied upon to indicate actual values. For the examples in this guide,

⁶Information on references can be found in [Clause 2](#).

miles and dollars are sometimes used for convenience; any other consistent unit of distance and cost will produce the same outcome.

5. Commonly used devices for switching and overcurrent protection

5.1 Overview

The subclauses in [Clause 5](#) describe the common devices used for switching and overcurrent protection. Typically, reclosers and fuses are used for overcurrent protection, as they are capable of interrupting fault current; switches are generally used for switching purposes; and sectionalizers are used in coordination with breakers or reclosers to switch open automatically. Most of these devices can be operated manually or through various remote control or distribution automation systems. New technology has been developed to enable fuses to be used to clear temporary faults. Some of these devices have communicating abilities, which is not in the scope of this guide; for additional information see IEEE Std 1854™.

5.2 Reclosers

A recloser is a protection device that can sense a high current flow, caused by a fault or overload, and interrupt that current flow before damage to the equipment occurs. The majority of faults on overhead distribution lines have been accepted as being temporary in nature [B2].⁷ These temporary faults are removed, or self-clear, after a short duration interruption in the current flow, with full power flow regained after re-energization of the feeder. The number of times that a recloser cycles through an interruption and re-energizes or recloses, as well as the length of time of those actions, is predetermined and configurable. The purpose of the multiple interruption and reclose actions is to allow the fault condition to be cleared, avoiding a permanent fault, thereby not subjecting the customer(s) to a sustained interruption.

Low-energy fault-testing reclosing technology may also be considered. This technology enables less energy let through for testing a fault in the line before initiating the reclosing sequence. Permanent faults may be isolated from the main line by the use of downstream line devices such as other reclosers, fuses, and sectionalizers. Coordination studies should be performed to check for compliance with company policy. Reclosers often make use of different tripping curves based on the number of reclose shots, as well as different open times between reclose attempts.

Consideration should be given when selecting a recloser, such that they are rated to break the maximum expected fault current and continuously carry the maximum expected load current.

5.2.1 Hydraulic reclosers

Hydraulic reclosers have a trip coil connected in series with the line current. When the line current exceeds the tripping threshold, a magnetic plunger is drawn into this coil. The plunger speed is determined by the actuating fault current and uses the forcing of oil through chambers or orifices for timing and sequencing purposes. Once the plunger reaches the full travel, the recloser contacts are opened. Typically, a hydraulic recloser will start to activate the plunger when the line current exceeds 200% of the coil rating.

5.2.2 Electronic reclosers

Electronic reclosers can be more flexible in their application. They may be controlled by an external device, such as a pre-specified solid state or pre-programmed microprocessor controller, that sends the recloser an open or close electric signal. Current, and in some cases voltage, transformer secondary values are supplied to the solid state or microprocessor controller. This enables the control to determine operation due to pre-determined time-current characteristics, trip current levels, and recloser operation sequences. Unlike hydraulic reclosers, electronic reclosers can be set to operate at any current level within a range without the need to

⁷The numbers in brackets correspond to those of the bibliography in [Annex B](#).

physically change out any internal components. On three-phase electronic reclosers, the phase and ground operating currents and time-current curves can be set independently. Electronic reclosers may also allow and facilitate the use of alternate, more sensitive settings during line maintenance activities. Compact single-phase electronic reclosers may be used in place of fuses to enable reclosing, fuse saving, and, in some cases, provide communication capabilities.

5.2.3 Three-phase versus single-phase reclosers

Both electronic and hydraulic reclosers are available for three-phase and single-phase applications. Some three-phase electronic reclosers are also capable of operating as single-phase tripping devices under certain conditions. Single-phase reclosers provide the ability to trip only the faulted phase. Since it is estimated that a large percentage of faults are single-phase faults [B2], tripping only the faulted phase keeps the customers on the other two phases from experiencing an outage. However, single-phase tripping could cause an issue known as single phasing to three-phase customers who may not have adequate protection. On heavily loaded feeders, tripping a single-phase recloser to lockout will cause significant unbalance to occur and care must be taken to prevent a source-side (or load-side) ground fault detection device from operating inadvertently. Most electronically controlled reclosers provide the option to trip and lockout single phase, trip single phase, but lockout three phase, or trip and lockout three phase.

A single-phase programmable electronic reclosing device may be suitable for some applications. These cutout mounted lateral/single-phase reclosers have a functionality similar to that of line reclosers, but operate at a lower continuous load rating. These may be considered when a fused cutout does not provide the needed lateral line or service transformer protection.

5.3 Sectionalizers

Sectionalizers are used in conjunction with a source-side reclosing device to provide an automatic sectionalizing point where coordination cannot be achieved with reclosers and fuses alone. Unlike other OCPDs, sectionalizers are not designed to clear a fault directly. Therefore, they do not have time-current curves associated with them. Instead, a sectionalizer is first activated by a high-current flow and then detects a near zero current to “count.” After a pre-determined number of “counts,” in a definite time period, the sectionalizer opens or “sectionalizes” during the next open period caused by a source side reclosing device and isolates the customer interruptions to the part of the feeder downstream from the sectionalizer. The minimum sectionalizer actuating current should be at most 80% of the minimum trip of the upstream device. This will provide the sectionalizer the ability to identify all recloser operations.

5.3.1 Hydraulic sectionalizers

A hydraulic sectionalizer has a current coil in series with the line current, which senses current similar to the coil found in a hydraulic recloser. Sectionalizers can be ordered with one, two, or three counts to operation. Care should be taken with one-count hydraulic sectionalizers, as inrush current could cause the upstream device to operate and the sectionalizer to isolate incorrectly.

5.3.2 Electronic sectionalizers

One type of electronic sectionalizer fits in a single-phase disconnect body (cutout) and may or may not be programmable. Thus, the sectionalizer current actuating level, number of counts, and reset time may be fixed or programmable. The sectionalizer falls open like a fuse and needs to be reset before it is returned to service. This type of sectionalizer generally contains inrush current restraint logic.

Both hydraulic controlled and electronic controlled sectionalizers are available for single- or three-phase applications. Some three-phase switches may also be outfitted with motor operators and electronic controls to function as sectionalizers.