



IEEE Guide for Automatic Reclosing on AC Distribution and Transmission Lines

STANDARDS

IEEE Power and Energy Society

Developed by the
Power System Relaying Committee

IEEE Std C37.104™-2022
(Revision of IEEE Std C37.104-2012)



IEEE Guide for Automatic Reclosing on AC Distribution and Transmission Lines

Developed by the

Power System Relaying Committee
of the
IEEE Power and Energy Society

Approved 9 February 2022

IEEE SA Standards Board

THIS IS A REDLINE DOCUMENT PRODUCED BY TECHSTREET, AN ASME COMPANY.

This document is intended to provide users with an indication of changes from one edition to the next. It includes a full-text version of the new document, plus an indication of changes from the previous version.

Redlines are designed to save time and improve efficiencies by using the latest software technology to find and highlight document changes. More professionals are using valuable new technologies like redlines, to help improve outcomes in a fast paced global business world.

Because it may not be technically possible to capture all changes accurately, it is recommended that users consult previous editions as appropriate. In all cases, only the current base version of this publication is to be considered the official document.

This Redline is produced solely by Techstreet. IEEE has not prepared this Redline and is not responsible for its accuracy.

Redline Processing Notes:

1. ~~Red Text~~ - Red strikethrough text denotes deletions.
2. Blue Text - Blue underlined text denotes modifications and additions.

Abstract: Accepted industry practices for application of automatic reclosing on transmission and distribution lines are documented in this guide. The guide discusses fundamentals of automatic reclosing, application considerations, and coordination practices. Application of emerging technologies for automatic reclosing is also discussed.

Keywords: automatic line sectionalizer, automatic reclosing, autoreclose blocking, autoreclose supervision, autoreclosing, dead time, fuse blowing scheme, fuse saving scheme, high-speed autoreclosing, IEEE C37.104™, leader-follower autoreclosing, reclosing, sync check, sync check supervision, time delayed autoreclosing, voltage supervision

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2022 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 28 April 2022. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-8454-1 STD25253
Print: ISBN 978-1-5044-8455-8 STDPD25253

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <https://www.ieee.org/about/corporate/governance/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers.html>), appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE SA) Standards Board. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers are not necessarily members of IEEE or IEEE SA, and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning this standard, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity, nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: THE NEED TO PROCURE SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE is the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that the presenter's views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, consulting information, or advice pertaining to IEEE Standards documents.**

Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its Societies and Standards Coordinating Committees are not able to provide an instant response to comments, or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in evaluating comments or in revisions to an IEEE standard is welcome to join the relevant IEEE working group. You can indicate interest in a working group using the Interests tab in the Manage Profile and Interests area of the [IEEE SA myProject system](#).¹ An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.²

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not constitute compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

¹Available at: <https://development.standards.ieee.org/myproject-web/public/view.html#landing>.

²Available at: <https://standards.ieee.org/content/ieee-standards/en/about/contact/index.html>.

Photocopies

Subject to payment of the appropriate licensing fees, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400; <https://www.copyright.com/>. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit [IEEE Xplore](#) or [contact IEEE](#).³ For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#).⁴ Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE Standards are developed in compliance with the [IEEE SA Patent Policy](#).⁵

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <https://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are

³Available at: <https://ieeexplore.ieee.org/browse/standards/collection/ieee>.

⁴Available at: <https://standards.ieee.org/standard/index.html>.

⁵Available at: <https://standards.ieee.org/about/sasb/patcom/materials.html>.

reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

IMPORTANT NOTICE

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. IEEE Standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

Participants

At the time this IEEE guide was completed, the D39 Working Group had the following membership:

Manish Patel, *Chair*
Rafael Garcia, *Vice Chair*
Joshua Lamb, *Secretary*

Jay Anderson	Wayne Hartmann	James O'Brien
Abu Bapary	Michael Higginson	Claire Patti
Jeffery Barsch	Binaya Joshi	Madhab Paudel
Mathew Black	Addis Kifle	Qun Qiu
Jorge Blumschein	Don Lukach	Miguel Rios
Brian Boysen	Bruce Mackie	Gregory Ryan
Sukumar Brahma	Deepak Maragal	Gary Stodter
Alla Deronja	Jezel Martinez	Paul Therrien
James Formea	Adi Mulawarman	Looja Tuladhar
Richard Gamble	Andrew Nguyen	Ilia Voloh
Mathew Garver		James Warren

The following members of the individual Standards Association balloting group voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

Jay Anderson	Kamal Garg	James O'Brien
Galina Antonova	Shubhanker Garg	Lorraine Padden
Abu Bapary	George Gela	Bansi Patel
Thomas Barnes	Jalal Gohari	Manish Patel
Jeffrey Barsch	Stephen Grier	Pathik Patel
Michael Basler	Gene Henneberg	Subhash Patel
David Beach	Michael Higginson	Charles Rogers
Martin Best	Werner Hoelzl	Thomas Rudolph
Steven Bezner	Robert Hoerauf	Daniel Sabin
Brian Boysen	Ali Hooshyar	Bartien Sayogo
Gustavo Brunello	Richard Jackson	Devki Sharma
Paul Cardinal	Anthony Johnson	Hyeong Sim
Sean Carr	James Kinney	P. Sivaraman
Stephen Conrad	William Knappek	Jerry Smith
Timothy Coyle	Konrad Erich Kork-	Gary Smullin
Randall Cunico	Schmitt	Wayne Stec
Robert Dempsey	Chung-Yiu Lam	Charles Sufana
Alla Deronja	An Le	David Tepen
Kevin Donahoe	Ting Li	Eric Thibodeau
Neal Dowling	Don Lukach	Michael Thompson
Donald Dunn	Bruce Mackie	Benton Vandiver
Paul Elkin	Todd Martin	John Vergis
William English	Jeffrey McElroy	Quintin Verzosa
James Formea	Dean Miller	Ilia Voloh
Carl Fredericks	Adi Mulawarman	John Wang
Fredric Friend	Anthony Napikoski	Karl Weber
Jean-Sebastien Gagnon	Arthur Neubauer	Kenneth White
Louis Garavaglia	James Niemira	Philip Winston
Rafael Garcia	Joe Nims	Murty V.V. Yalla

When the IEEE SA Standards Board approved this guide on 9 February 2022, it had the following membership:

David J. Law, *Chair*
Vacant Position, *Vice Chair*
Gary Hoffman, *Past Chair*
Konstantinos Karachalios, *Secretary*

Edward A. Addy
Ted Burse
Ramy Ahmed Fathy
J. Travis Griffith
Guido R. Hiertz
Yousef Kimiagar
Joseph L. Koepfinger*
Thomas Koshy

John D. Kulick
Johnny Daozhuang Lin
Kevin Lu
Daleep C. Mohla
Andrew Myles
Damir Novosel
Annette D. Reilly
Robby Robson
Jon Walter Rosdahl

Mark Siira
Dorothy V. Stanley
Lei Wang
F. Keith Waters
Karl Weber
Sha Wei
Philip B. Winston
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C37.104-2022, IEEE Guide for Automatic Reclosing on AC Distribution and Transmission Lines.

Since most faults on overhead distribution and transmission lines are temporary in nature, the automatic reclosing is commonly applied to quickly re-energize a line to restore system integrity, service to customers, or both. This guide presents generally accepted industry practices for application of autoreclosing on both distribution and transmission lines.

[Clause 4](#) discusses fundamentals of automatic reclosing such as autoreclose settings, autoreclose supervision, autoreclose blocking, and general application considerations on distribution and transmission lines.

[Clause 5](#) focuses on autoreclosing practices for distribution lines. Distribution lines often contain sectionalizing equipment such as circuit breakers, fuses, reclosers, and sectionalizers to isolate faulted sections of the line. Autoreclosing coordination practices involving coordination with circuit reclosers, automatic line sectionalizers, fuse saving and fuse blowing schemes, as well as distributed energy resources are presented.

[Clause 6](#) focuses on autoreclosing practices for transmission lines. Application considerations for high-speed autoreclosing, single-phase tripping and autoreclosing, impact on stability and turbine-generator, series compensated lines, lines with in-series or tapped transformers, multi-terminal lines, line sectionalizing schemes, etc., are discussed in detail.

The application of emerging technologies such as use of ethernet based, point-on-wave and pulse closing for autoreclosing is discussed in [Clause 7](#). Application of using fault location on hybrid or mixed line for autoreclosing and multi-phase tripping and reclosing are also presented in this clause.

This guide is intended for engineers who have knowledge of power system protection. This is an application guide and may not cover the considerations for all scenarios. Additional reading material is suggested in the Bibliography ([Annex A](#)).

Contents

1. Overview.....	11
1.1 Scope.....	11
1.2 Purpose.....	11
1.3 Word usage.....	11
2. Normative references	12
3. Definitions, acronyms, and abbreviations	12
3.1 Definitions.....	12
3.2 Acronyms and abbreviations	14
4. Fundamentals and applications	14
4.1 General	14
4.2 Basics of autoreclosing function.....	15
4.3 Autoreclosing nomenclature.....	16
4.4 Autoreclosing circuitry and logic.....	17
4.5 Autoreclosing settings	20
4.6 Autoreclosing supervision	22
4.7 Autoreclose blocking.....	25
4.8 Application considerations	27
4.9 Substation controller.....	31
4.10 SCADA	32
5. Autoreclosing for distribution systems.....	32
5.1 Distribution system overview.....	32
5.2 Distribution autoreclosing practices	33
5.3 Autoreclosing coordination practices	34
5.4 Application considerations	39
6. Autoreclosing for transmission systems	41
6.1 Overview of autoreclosing on transmission system.....	41
6.2 Autoreclosing methods.....	41
6.3 Application considerations	46
7. New technologies/special applications.....	62
7.1 Ethernet based applications to autoreclosing.....	62
7.2 Fault location to supervise reclosing on mixed line	64
7.3 Point-on-wave (POW) and staggered pole autoreclosing	65
7.4 Multi-phase tripping and autoreclosing	66
7.5 Pulse closing.....	67
Annex A (informative) Bibliography.....	68
Annex B (informative) History of automatic reclosing	76
Annex C (informative) Sample method to indicate autoreclosing mode and timing	78

IEEE Guide for Automatic Reclosing ~~on~~ of ~~Circuit Breakers for~~ AC Distribution and Transmission Lines

~~IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.~~

~~This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Documents." They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.~~

1. Overview

1.1 Scope

This guide documents present practices regarding the application of automatic reclosing control to line circuit breakers: or other line interrupting devices. Both transmission and distribution line practices are addressed. ~~The guide is not intended to provide guidance for the operation of the bulk power system in matters of reclosing, such as enabling or disabling automatic reclosing or providing for manual closures following automatic tripping of an element.~~

1.2 Purpose

The guide ~~describes~~ ~~provides~~ benefits of automatic reclosing and ~~includes~~ ~~provides~~ application considerations for proper coordination with other system controls ~~(e.g., auto sectionalizing, fast valving, etc)~~. The guide includes a section on emerging technologies ~~(e.g., IEC 61850)~~ and their application to automatic reclosing. ~~Supplementary information is comprised of annexes containing a bibliography of technical literature concerning reclosing as well as a brief history of the use of automatic reclosing.~~

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*).^{6,7}

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*).

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

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

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 C37.04⁰⁶™, IEEE Standard for [Ratings and Requirements for](#) AC High-Voltage Circuit Breakers [with](#) Rated [Maximum Voltage](#) ~~on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities for Voltages~~ Above 1000 V. [8.9 1,2](#)

~~IEEE Std C37.04™, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers.~~

IEEE Std C37.60™, IEEE Standard Requirements for Overhead, Pad Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems.

IEEE Std C37.63™, IEEE Standard Requirements for Overhead, Pad Mounted, Dry Vault, and Submersible Automatic Circuit Sectionalizers for AC Systems.

IEEE Std C37.116™, IEEE Guide for Protective Relay Application to Transmission-Line Series Capacitor Banks.

[8 4](#) The IEEE standards or products referred to in ~~this~~ Clause [2](#) are trademarks [owned by](#) ~~of~~ The Institute of Electrical and Electronics Engineers, [Incorporated](#) ~~Inc.~~

[2 2](#) IEEE publications are available from The Institute of Electrical and Electronics Engineers, ~~445 Hoes Lane, Piscataway, NJ 08854, USA-~~ ([https](https://standards.ieee.org/) ~~http~~://standards.ieee.org/).

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. [10 3](#)

automatic: Refers to either local or remote switching operations that are initiated by relay or control action without the direct intervention of an operator.

automatic circuit recloser: A self-controlled device for automatically interrupting and reclosing an alternating-current circuit, with a predetermined sequence of opening and reclosing followed by resetting, hold-closed, or lock-out operation.

automatic line sectionalizer: A self-contained circuit-opening device that automatically opens the main electrical circuit through it after sensing and responding to a predetermined number of successive main current impulses equal to or greater than a predetermined magnitude. It opens while the main electrical circuit is de-energized. It may also have provision to be manually operated to interrupt loads.

autoreclosing: The automatic closing of [an interrupting device](#) ~~a circuit breaker~~ in order to restore [a power system](#) ~~an~~ element to service following automatic tripping of [that device](#) ~~the circuit breaker~~. ~~Autoreclosing does not include automatic closing of the circuit breakers associated with shunt or series capacitor banks or shunt reactors.~~

~~**blocking:** Refers to the automatic prevention of an action following specific relay tripping operations.~~

NOTE—May also be referred to as ‘reclosing’ in this guide.¹¹

[10 3](#) *IEEE Standards Dictionary Online* ~~subscription~~ 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~~ http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

^{11 4} Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

breaker autoreclosing time: The elapsed time between the energizing of the breaker trip coil and the closing of the breaker contacts to re-establish the circuit on the autoreclose operation.

dead time: That period of time the [interrupting device](#) ~~circuit breaker~~ is open, and the controlled circuit is de-energized following the tripping operation for a fault and before the autoreclosing attempt. *Syn:* [open interval](#).

NOTE—The dead time is also widely referred as reclose interval.

delayed autoreclosing: [A type of](#) ~~Refers to the~~ autoreclosing [where an interrupting device closes](#) ~~of a circuit breaker~~ after [an intentional](#) a time delay ~~that is intentionally longer than that for high-speed autoreclosing.~~

drive-to-lockout: The process of forcing the autoreclosing function to its lockout state.

high-speed autoreclosing: [A type of](#) ~~Refers to the~~ autoreclosing [where an interrupting device closes](#) ~~of a circuit breaker~~ after a [minimal intentional](#) ~~necessary~~ time delay to [allow for](#) ~~permit~~ fault arc deionization [and achieve the fastest restoration time](#) ~~with due regard to coordination with all relay protective systems. This type of autoreclosing is generally not supervised by voltage magnitude or phase angle.~~

lockout: The state of the reclosing relay [or reclosing device](#) wherein the controlled [interrupting device](#) ~~line breaker~~ is open and ~~the relay disabled from making~~ any further [automatic reclosing](#) ~~reclose~~ attempts [are disabled](#).

manual: Refers to either local or remote switching operations that are initiated by an operator.

multiple-shot autoreclosing: Refers to the autoreclosing of [an interrupting device](#) ~~the circuit breaker(s)~~ more than once within a predetermined autoreclosing sequence.

[open interval:](#) *See:* [dead time](#).

permissives: Those measured functions or system conditions that must be satisfied prior to allowing the reclosing action to proceed.

protective reclosing relay: A Programmable relay whose function is to detect defective lines or apparatus or other power system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action ~~the automatic reclosing of a circuit breaker.~~

NOTE—A protective relay may be classified according to its operating principle or performance characteristics.

reclosing device: A control device that initiates the reclosing of a circuit after it has been opened by a protective relay.

reclosing relay: A function within a multifunction programmable device, or a dedicated device, whose purpose is to initiate automatic reclosing of a circuit breaker or other interrupting device.

shot: Autoreclose attempt that is initiated by command of the reclosing logic.

single-phase autoreclosing: *See ~~also~~:* **single-pole autoreclosing.**

single-pole autoreclosing: Refers to the autoreclosing of one phase of an interrupting device ~~a circuit breaker~~ following a designed single-phase trip for single-phase-to-ground faults. *Syn:* ~~Also referred to as~~ **single-phase autoreclosing.**

sync check: *See ~~also~~:* **synchronism check.**

synchronism check: A verification that voltages on both sides of an interrupting device ~~the breaker~~ are within predetermined limits of magnitude, phase angle, and frequency. *Syn:* sync check.

transfer trip: A form of remote trip in which a communication channel is used to transmit a trip signal from the relay location to a remote location.

3.2 Acronyms and abbreviations

CAIDI customer average interruption duration index

DER distributed energy resource

EHV extra high voltage

HBDL hot-bus/dead-line

HLDB hot-line/dead-bus

IBR inverter-based resource

LTC load tap changers

MAIFI momentary average interruption frequency index

MOV metal oxide varistors

PMU phasor measurement unit

POW point-on-wave

SAIDI system average interruption duration index

SAIFI system average interruption frequency index

SCADA supervisory control and data acquisition systems

TRV transient recovery voltage

WTG wind turbine generator

4. Fundamentals and applications

4.1 General

This clause describes fundamental concepts common to automatic reclosing for both transmission and distribution line breakers ~~or other line interrupting devices~~. In the most common applications, automatic reclosing is performed following a protective relay trip for a fault on the protected line, in particular, where there is a good probability that the fault was temporary ~~(such as in case of overhead lines)~~, and automatic reclosing can be used to quickly re-energize the line to restore system integrity, service to customers, or both. ~~The However, as discussed,~~ circuit breakers may also be automatically reclosed following a protective relay-initiated bus trip, again where there is a good possibility that the fault was temporary and automatic reclosing ~~speeds will speed~~ restoration of the bus and system integrity. ~~However, autoreclosing following bus faults is not in the scope of this guide.~~

As most faults on overhead electrical systems are temporary in nature, the use of automatic reclosing (autoreclosing) aids in the restoration of the system in a timely manner, much more quickly than is possible by ~~local~~ manual (local or supervisory) ~~remote manual~~ control. To apply autoreclosing properly, several factors ~~may should~~ be considered. Some of the most common considerations are as follows:

- a) What is the probability of successfully reclosing the circuit following a trip?
- b) What is the potential for damage to the system components by autoreclosing into a fault?
- c) Are special interlocks required to inhibit autoreclosing under certain conditions?
- d) Should the autoreclosing be time-delayed or is high-speed autoreclosing allowed or desirable?
- e) How many autoreclosing attempts should be used for the application?
- f) Should voltage supervision be applied?

- g) Should there be a synchronism check?
- h) What are the consequences of not autoreclosing?
- i) On networked lines, which ~~what~~ terminal of the line should be selected as the lead reclosing terminal?
- j) How should autoreclosing be initiated?
- k) Is there generation connected to the bus such that high-speed reclosing could cause torsional oscillations to the generator turbine shaft?

These fundamental questions are discussed in the remainder of this guide.

4.2 Basics of ~~The autoreclosing function performed by a reclosing relay~~

Reclosing can be ~~The autoreclosing function has traditionally been~~ performed by ~~a reclosing relay~~ ~~that is~~ dedicated relays; ~~to a specific circuit breaker.~~ however, the autoreclosing function can also be performed by any number of devices capable of identifying ~~or processes that get an input to identify~~ when the circuit breaker, or in some distribution applications, the recloser, is opened or closed, and, in some cases, how the breaker is tripped, ~~i.e., manually, or by protective relay action.~~ Programmable logic controllers, substation controllers, recloser controllers, ~~computers~~ and even supervisory control and data acquisition systems (SCADA) ~~systems~~ have been used to perform the autoreclosing function. Many modern ~~Most~~ microprocessor-based transmission line and distribution feeder protective relays and recloser controls have a built-in autoreclosing function. ~~For the sake of consistency, this document refers to a reclosing relay as a device that performs the autoreclosing function, regardless of whether it is a separate relay, or it is a function within a protective relay, or it is simply logic programmed into another device.~~

A typical reclosing ~~The autoreclosing~~ function has ~~can be considered to be in one of~~ four ~~distinct~~ states as follows:

- Ready ~~Reset~~ state: The circuit breaker is closed and the autoreclose function is waiting to receive an initiate to start timing to reclose after the breaker opens.
- Reclosing in progress ~~Cycle~~ state: The circuit breaker is open and the autoreclose function is timing toward its set time to close the circuit breaker; (potentially waiting for supervisory conditions such as voltage supervision, sync check, etc., to be satisfied), ~~or~~; the circuit breaker is closed following a successful autoreclose, timing toward its set time to return to the ready ~~reset~~ state.
- Lockout state: The autoreclosing function has advanced through its programmed or set sequence of circuit breaker close operations, and in each case the protective relay has detected a fault and tripped the circuit breaker ~~open again~~. The circuit breaker is now tripped ~~open~~ and locked out, meaning that the circuit breaker can ~~must~~ now only be closed by some other means (via local- or supervisory control). Other triggers for autoreclose lockout may include manual or remote manual trip (either local or supervisory), breaker failure trip, a trip resulting from high current faults and/or three phase faults, time delayed trip, automatic load shedding (underfrequency and undervoltage), or out of step tripping, etc.
- Not ready ~~Power-up~~ state: May be used in some reclosing ~~autoreclosing~~ relays when the relay is powered up. In this state, the reclosing ~~autoreclose~~ relay assesses its inputs to determine the state of the breaker and the autoreclose initiate and supervision inputs. After assessing these inputs, the reclosing ~~autoreclose~~ relay typically changes to the ready ~~reset~~ state if the breaker is closed and no other inputs are active, or to the lockout state if the breaker is open or if drive-to-lockout inputs are active.

When the autoreclosing function is in the ready ~~reset~~ state, the autoreclosing function can be initiated in one of two ways to start timing toward its first ~~initial~~ autoreclose attempt, depending on the device design or scheme logic:

- Detecting that the breaker opened, which starts the timing of the first ~~open~~/reclose interval, ~~or~~ or.
- Detecting that the protective relay tripped the circuit breaker, followed by confirmation that the breaker opened, which starts the timing of the first ~~open~~/reclose interval.

When the ~~controlled~~-breaker opens, the reclosing relay starts timing toward its first ~~initial~~ autoreclose attempt. This transition to timing toward the first autoreclose attempt changes the reclose function from the ready ~~reset~~ state to the reclosing in progress ~~cycle~~ state. At the completion of this delay, the reclosing relay closes its output contact to initiate breaker closing and confirms that the breaker has closed through a state change of the breaker status input. If the breaker fails to close within a predetermined time, the reclosing relay is commonly driven ~~may go~~ to lockout, releasing the close output, or continues ~~continue~~ to assert the close output, depending on the reclosing relay design and programming. When the breaker closes, the reclosing relay starts its reset timer (also known as reclaim timer). If the breaker stays closed, indicating that the fault was temporary, then the reclosing relay continues timing toward reset. At the completion of the reset time delay, the autoreclosing function returns to the ready ~~reset~~ state and remains there as long as the breaker is still closed.

If the fault is not cleared and the protection scheme initiates a second trip, the reset timer is stopped and reset, and the reclosing relay begins timing toward a second autoreclose ~~autoreclosing~~ attempt if it is programmed or set for more than one autoreclose attempt. If after any of the autoreclose attempts the breaker remains closed for the duration of the reset ~~delay~~-timer, the reclosing relay returns to the ready ~~reset~~ state.

If the fault is permanent and the number of programmed/set autoreclosing attempts expires, the reclosing relay advances to the lockout state, leaving the breaker open. The autoreclosing function is now “locked out” until the breaker is closed by other means. After the breaker closes, and depending on the design of the reclosing relay, the relay may then reset immediately or after a reset time delay. This may be the same reset delay used for successful reclose, or a different delay used exclusively for from the lockout condition. In the event that the breaker is manually closed and fails to remain closed, reclosing relay circuitry/logic is should be designed to prevent the reclosing relay from operating. Likewise, it may also be desirable to prevent the reclosing relay from resetting if closing the breaker causes protective relay elements to pick up and start timing to trip. When reclosing relay closes the breaker, reclosing relay reset timer starts. In case of a low magnitude permanent fault or line loading just above the pickup setting of a time delayed protective relay element, timer for protective relay element starts as well. If the reset time delay is less than the tripping time delay, reclosing relay resets first and then breaker trips. The process repeats as the reclosing relay never advances to the lockout state and a breaker pumping condition can occur which may ultimately lead to breaker damage, system equipment damage, and possible public hazard. The use of longer reset timer delay is one alternative to avoid this condition; another alternative is to stall reclosing relay from resetting when protective relay element is picked up and timing.

4.3 Autoreclosing nomenclature

There are many reclosing autoreclosing relay designs in service today. Electromechanical, solid state, and microprocessor-based reclosing autoreclosing relays or other devices that perform the reclosing function work similarly functions are similar in many respects, but may have subtle design differences. These differences may be important when comparing and documenting autoreclosing schemes and settings. Nomenclature is important to make sure that the documentation conveys a clear understanding of the autoreclosing scheme operation.

Autoreclose timing nomenclature is an important aspect of autoreclosing scheme documentation. Timing nomenclature varies with the type or manufacturer of reclosing relays. Also, the same autoreclosing sequence may be documented in different ways, leading to confusion about the desired and actual scheme performance.

For example, a reclosing ~~an autoreclosing~~ relay may have an inherent closing time delay of 0.2 s, whereas another reclosing relay may have virtually no inherent time delay. In the first case, an instantaneous reclose (having no intentional time delay) may be described as having a reclose time of 0.0 s, however, ~~when~~ it ~~will~~ actually has ~~have~~ a reclose time of 0.2 s because of the reclosing relay's inherent time delay. Conversely, if the scheme is described as having a first reclose time of 0.2 s to account for the inherent time delay, and if this is interpreted ~~construed~~ by others to mean that the reclosing relay considered to ~~should~~ be set with an intentional reclose time of 0.2 s, the actual reclosing delay will be 0.4 s. Also, if both types of reclosing relays are set with a reclosing delay setting of 0.2 s for consistency, the reclosing relay with virtually no inherent time delay will issue a ~~its breaker~~ close command 0.2 s faster than the reclosing relay with the inherent time delay, possibly leading to damaged motors or generators that are re-energized before their isolating devices have had a chance to operate.

Additional confusion can arise in how multiple autoreclosing shots are indicated. For example, a two-shot autoreclosing may be described as having a sequence of 15 s and 30 s reclosing times. The 30 s may indicate the time after the first autoreclose attempt ~~failed and the breaker tripped a second time~~, or it may indicate the total elapsed time from the initial trip. In the first instance, this means the second attempt occurs ~~at the 45 s point~~ after the initial trip or reclose initiation. In the second interpretation, this means the second attempt occurs 30 s after the initial trip or reclose initiation.

Some reclosing relays control autoreclosing using an open interval time that typically starts after the breaker opens. Microprocessor-based relays may also have additional settings to stall the open interval timing if the tripping logic is still asserted, skip reclosing shots if specific conditions are not met, and stall reset. Sequence coordination is also commonly used with multi-shot reclosing on distribution lines ~~circuits~~ to coordinate with fast and delayed curve tripping between series connected protective devices- (see 5.3.4).

Additionally, ~~Even more basic is that~~ some devices define reclosing or open interval time delay settings in seconds or fractions of a second, while others may be set in cycles or fractions of a cycle. So, it is extremely important that the nomenclature used to document the autoreclosing scheme operation and settings is ~~be~~ clear and concise to avoid confusion and possible damaging effects of improper autoreclosing.

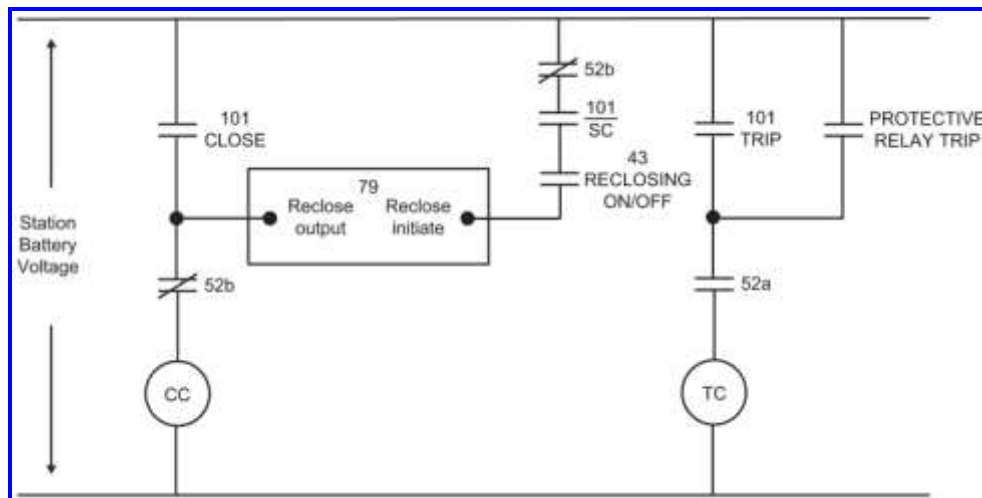
See Annex C for a sample method of indicating the autoreclosing mode and timing. The annex also presents a timeline for a sample autoreclosing scheme.

4.4 Autoreclosing circuitry and logic

Reclosing relays that perform ~~Autoreclosing is initiated either by~~ the autoreclosing function based ~~transition of a circuit breaker auxiliary contact~~ on only a breaker status contact (52a opening or 52b closing) cannot distinguish if the breaker opening was due to a manual operation or a ~~or by~~ protective relay operation. Other reclosing relays or devices that perform the reclosing function might use an indication from a protective relay trip, and possibly a breaker status contact. For this reason, ~~both. Control circuitry or logic is required so that circuit breakers autoreclose only when intended,~~ the control circuitry/logic is different depending on the type of autoreclose initiation required by the reclosing relay design and its available features. If ~~the reclosing relay~~ is to be initiated by a breaker status contact ~~(52a opening or 52b closing)~~, then additional control circuitry or logic is employed ~~needed~~ to distinguish between a local ~~manual control switch~~ or remote manual control trip, and a protective relay trip, since autoreclosing is not desired following ~~for~~ a ~~local~~ manual opening of a breaker ~~or remote trip~~.

One technique used to prevent autoreclosing ~~following a~~ local-manual ~~trip trips~~ is to install a slip contact of the circuit breaker control switch in series with ~~reclose the reclosing relay close~~ initiation input ~~of the reclosing relay~~. This contact of the circuit breaker control switch disengages when the circuit breaker is manually opened. It engages when the circuit breaker is manually closed. This ~~slip contact in series with reclose initiation input combination~~ prevents the reclosing relay from recognizing the open position of the circuit breaker when it is manually tripped, and permits the reclosing relay to reclose the circuit breaker automatically when it trips for a fault following a manual closure. Alternatively, and especially with microprocessor-based relays, the control circuit can be designed to lockout reclosing for manual circuit breaker trips.

~~NOTE—Slip contact generally refers to contacts that remain closed in the normal after close or normal after trip position. The slip contact used in the autoreclosing logic remains closed in the normal after close position.~~4



(New)

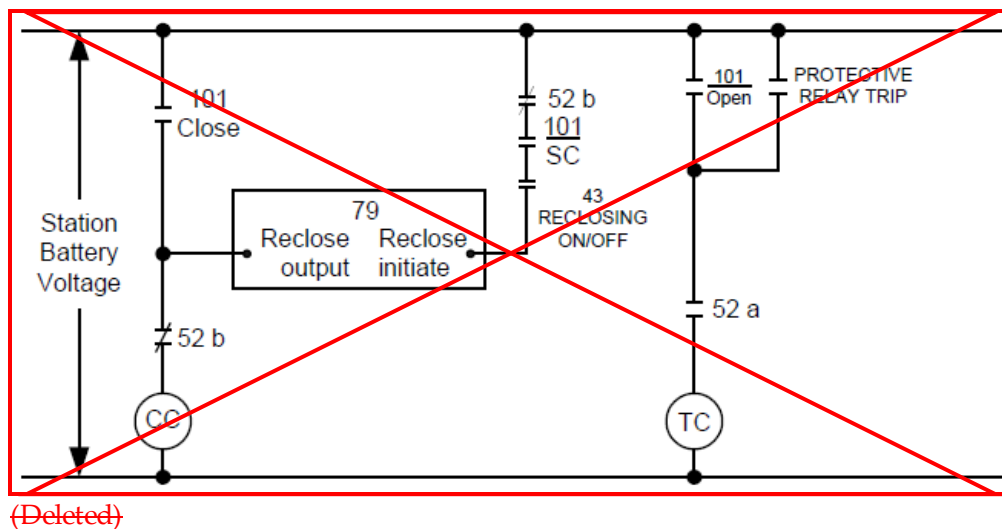


Figure 1 – Control circuit design with slip contacts and reclosing ON/OFF switch

Figure 1 illustrates a simplified control circuit with [breaker status initiated](#) autoreclosing. Contacts shown in the figure include [the following](#):

- 101: Manual breaker control switch.
- 101/CLOSE: Contact [closes](#) ~~closed~~ when control handle turned to CLOSE position, contact [remains](#) open when control handle turned to TRIP position [or when](#) ~~and~~ in the normal-after-close [or](#) ~~and~~ normal-after-trip position.
- 101/TRIP ~~Open~~: Contact [closes](#) ~~closed~~ when control handle [is](#) turned to TRIP position, contact [remains](#) open when control handle turned to CLOSE position [or when](#) ~~and~~ in the normal-after-close [or](#) ~~and~~ normal-after-trip position.
- 101/SC: [\(slip contact\)](#): Contact [closes](#) ~~closed~~ when control handle [is](#) turned to CLOSE position [or when](#) ~~and~~ in the normal-after-close position. [Contact opens](#) ~~contact open~~ when control handle [is](#) turned to TRIP position [or when](#) ~~and~~ in the normal-after-trip position.
- 43/Reclosing On/Off control switch: Contact closed when reclosing is ~~to be~~ enabled (43/ON), otherwise open (43/OFF).

- 52a: Breaker position auxiliary switch, closed when main breaker contacts are closed, and open when main breaker contacts are open.
- 52b: Breaker position auxiliary switch, closed when main breaker contacts are open, and open when main breaker contacts are closed.

4.4.1 Understanding [of](#) selective autoreclosing logic

Autoreclose logic has been applied in many ways, primarily because there are many application scenarios and different opinions on the best way to address them. Autoreclosing logic can be set up to recognize and respond to specific system conditions, providing selectivity to the reclose function. Selective autoreclosing is most often used where the possible negative effects of autoreclosing into a specific type of fault or system condition are deemed unacceptable. There are several reasons to provide selective breaker automatic reclosing, including [the following](#):

~~— Reclosing for protective relay tripping, and not for manual and remote/SCADA tripping~~

- Reclosing for selected fault types, such as phase-to-phase and phase-to-ground faults that are typically temporary faults, and not for three-phase faults that are more likely to be permanent.
- [Reclosing considerations on lines terminating at generating plants or with large motor loads and when system stability is of concern.](#)
- High-speed [autoreclosing](#) ~~reclosing~~ for pilot scheme/communications-assisted tripping, and delayed [autoreclosing](#) ~~reclosing~~ for non-pilot trips that may involve delayed tripping.
- Reclosing only when the line side of the breaker is dead to verify that downstream or remote generation is off-line.
- Reclosing only when the line side of the breaker is energized to verify that the remote line breaker is closed and the line is no longer faulted.
- Reclosing only when sync check function allows.

Selective autoreclosing schemes control reclose operations in one of two ways: limiting the initiation of reclosing logic, or blocking reclosing logic after it has been initiated. It is possible for selective autoreclosing logic to use both these methods in a single scheme.

Most, ~~if not all,~~ selective autoreclosing schemes use the operation of specific [protective](#) relays or relay elements to initiate the scheme. ~~With electromechanical relays, the reclosing is initiated either by the breaker status contact and/or protective relay operation.~~ The advent of microprocessor relays with the ability to assign specific relay elements to output contacts has allowed for very flexible selective autoreclosing schemes. Some schemes only initiate autoreclosing for pilot (communication assisted) trips ~~where it is likely that a similar pilot trip will occur if the fault re-establishes on autoreclose.~~ Others avoid autoreclosing for conditions such as: multiphase faults where system stability is of concern, time-delayed trips ~~where pilot is used, when,~~ out-of-step [trip](#), tripping is used or where sensitive or critical loads can be affected [as well as for other reasons](#).

~~Where the Autoreclose blocking can be similarly applied by initiating~~ reclosing relay [simply monitors](#) ~~operation for any~~ breaker [status, additional trip and using](#) blocking logic [is used](#) to stop and reset [reclosing](#) ~~reclose~~ relay operation, or block the [reclosing](#) ~~reclose~~ relay close output if the breaker is tripped [by non-protective relay operation.](#) ~~manually, either locally or remotely.~~ The blocking logic [is](#) ~~may be more~~ complicated because it [operates](#) ~~must operate~~ before the first reclose time occurs and because the reclosing relay [is](#) ~~must be~~ allowed to run to lockout before the block is removed. Failure to verify that the [reclosing](#) ~~reclose~~ relay is in the lockout or [ready](#) ~~reset~~ state before removing the block can result in unexpected and undesired breaker closing operations, so simply halting [reclosing](#) ~~reclose~~ relay operation is not an option. [The concerns addressed here may not be applicable to modern microprocessor-based relays.](#)

In some cases, such as reclosing for only selected line voltage conditions, reclose blocking is the more acceptable choice because there will be a time delay between breaker tripping and when the line voltage condition is checked. The reclosing cycle is allowed to run to the first reclose time, at which point the line voltage is checked to determine if the conditions are suitable for closing. If not, the reclosing relay close output is blocked from closing the breaker, and the reclosing ~~reclose~~ relay is either driven to lockout, cycled to the next reclose time interval (if applicable), or allowed to wait for a period of time until the acceptable line voltage condition occurs. In this latter case, the waiting time period may be restricted to prevent unexpected and undesirable long delayed breaker closing ~~at a much later time~~.

Finally, when contemplating a ~~When applying~~ selective autoreclosing, scheme, consider ~~one should bear in mind that faults are often dynamic in nature.~~ the probability of reclosing ~~autoreclosing~~ into unacceptable conditions versus the consequences ~~needs to be weighed against the likelihood of an unnecessary delay in re-energization if reclosing is falsely blocked.~~ For example, with a selective reclosing scheme based on fault type, consider that faults are often dynamic in nature ~~the fault not reigniting~~ and that relay ~~therefore re-establishing the circuit in a timely manner.~~ Some ~~microprocessor~~ algorithms may not always properly identify the fault type, In either case, a selective scheme ~~which~~ could unnecessarily prevent, reclosing ~~proper autoreclosing~~ or allow reclosing ~~autoreclosing~~ when not intended. For low risk and/or low probability scenarios, the complexity of a selective scheme may not offer enough benefit to outweigh potential problems depending on its purpose. However, for higher impact cases such as those related to system stability or damage to costly assets, choosing to selectively delay or block reclosing is worth consideration.

4.4.2 Understanding ~~of~~ device internal logic and processing

To design reclosing controls using microprocessor relays, understanding ~~the designer should first understand~~ how, and in what order, the relay processes the programmable logic is critical. Since every element and word bit in the relay cannot be scanned and processed simultaneously, the relay intrinsically has ~~will have~~ some type of specific scanning and processing order. This information is usually found in the relay instruction manual, but the designer may have to consult ~~refer to~~ the relay manufacturer ~~factory~~ for this information. As an example, one manufacturer's programmable logic controller processes its logic top-to-bottom and left-to-right one rung at a time based on the logic ladder diagram. Other manufacturer's relays process all logic within a specific time interval, usually several times in a power system cycle. During this interval, all inputs are scanned, internal and intermediate logic is processed, and the resulting logic is applied to virtual or hardware outputs, providing a deterministic operating time.

4.5 Autoreclosing settings

4.5.1 Number of reclosing attempts

Single-shot autoreclosing is the autoreclosing of a circuit breaker or another interrupting device one time, ~~often~~ within a prescribed period. This can be either high-speed or time-delayed. Multiple-shot autoreclosing is the autoreclosing of a circuit breaker or another interrupting device more than one time in a predetermined autoreclosing sequence. ~~Multiple-shot~~ Autoreclosing systems are typically ~~should be~~ designed considering available air or gas pressure for breaker operation, system stability, potential equipment damage due to excessive current or heating, (breaker de-rating factor for reclosing in less than a predetermined time), and potential adverse effects to customers and their equipment.

4.5.2 Dead time

Several factors are important to consider before attempting to autoreclose any circuit breaker that has just tripped for a fault. Although the goal is to restore the line to service as quickly as possible, one factor to consider is re-establishment of circuit breaker's dielectric strength (refer to 4.8.3 for more details) after interruption of a fault current. An autoreclose attempt without sufficient time delay to allow circuit breaker's ~~the~~ dielectric strength to re-establish may result ~~its strength results~~ in the circuit breaker failing to successfully open for an unsuccessful reclose attempt.

Another factor is to consider is the ionized-gas path created by the fault arc. This path created by the fault arc will start conducting again after the autoreclose if sufficient time is not allowed for the gas to disperse. The deionization time depends on the voltage, the conductor spacing, the magnitude of fault current, and the weather conditions (see Electrical Transmission and Distribution Reference Book [B119]).¹² ~~Westinghouse Electric Corporation [B103]).⁵~~ An example of an appropriate ~~a good~~ minimum time delay is given by Equation (1) for deionization of air at the fault location: (see Blackburn, J.L. [B19]):

$$t = 10 \cdot 5 + VL-L / 34 \cdot 5 \quad (1)$$

where

t is time expressed in cycles, ~~and~~

$VL-L$ is rated line-to-line voltage (kV);

¹² ⁵ The numbers in brackets correspond to those of the bibliography in Annex A.

Equation (1) is developed based on 40 years of operating experience (Westinghouse Electric Corporation [B120]). This equation applies where all three phases are opened and there is no trapped energy, such as from shunt reactors, or induction from parallel lines. The arc deionization time can increase if a nearby adjacent parallel line helps to sustain the arc or if single-phase tripping is used and the energized phases sustain the arc. The de-ionization time also greatly depends on a fault clearing time. Equation (1) does not incorporate fault clearing time directly. It is unknown if impact of fault clearing time was incorporated in operational experience that was used to derive this equation.

The Electrical Transmission and Distribution Reference Book [B119] summarized estimated deionization time for successful reclosure based on available information in Griscom and Torok (see [B42]), which is less than that achieved by using Equation (1). Note that estimated deionization time in the Electrical Transmission and Distribution Reference Book [B119] is based on a reference published in 1933, whereas Equation (1) was derived in mid 1970s. A comparison of deionization or dead time with both is shown in Table 1. Dead time based on Equation (1) is rounded up to a next whole number.

Table 1—Comparison of minimum deionizing or dead time

Nominal system voltage (kV)	Minimum deionizing or dead time		
	Electrical Transmission and Distribution Reference Book (see [B119])		Equation (1) (cycles)
	95% confidence (cycles)	75% confidence (cycles)	
23	4	—	12
45	5	3.5	12
69	6	4	13
115	8.5	6	14
138	10	7.5	15
161	13	10	16
230	18	14	18

(New)

Depending on individual utility's operating experience, best practices, system configuration, and line voltage, application of dead time may vary.

For some types of circuit breakers, a delay is often ~~needs to be~~ added to either the breaker time or the autoreclose time in order to exceed the arc deionization time. For example, breakers are available that can reclose in as little as two or three cycles; the application of such breakers will require a delay to avoid reclosing before the arc extinguishes.

4.5.3 Autoreclosing reset time and autoreclosing lockout

A reset timer is typically provided in a reclosing relay to reset the relay after successful autoreclosure of the circuit interrupting device. If the autoreclosing is successful, the reclosing relay returns to its ready ~~reset~~ state after the reset time delay expires. Selection of the reset delay may depend on the nature of the fault and expected clearing time. For example, a longer reset delay reduces ~~will reduce~~ the possibility of excessive tripping and autoreclosing for intermittent faults. A delay shorter than the duration between intermittent faults allows ~~will allow~~ the reclosing to reset, thereby preventing lockout. Lengthening of the reset time on the reclosing relay prevents the excessive operations but could cause a ~~undesirable~~ lockout operation that may or may not be desirable ~~operations~~.

If the autoreclosure is not successful, (for example, in case of a permanent fault), the reclosing relay moves to a lockout state ~~position~~ so that the interrupting device cannot be automatically closed. Autoreclosing is locked out, or terminated, after the programmed number of attempts to reenergize the line are tried and unsuccessfully completed. The lockout state also helps prevent ~~condition is useful in preventing~~ excessive wear on the interrupting device from multiple operations due to frequent transitory faults on the line, such as tree limbs ~~affected by wind~~ and galloping conductors.

Some autoreclosing systems can be programmed to provide a lockout condition to prevent subsequent autoreclosing if the number of faults exceeds a certain number within a window of time. For example, a three-shot autoreclosing system could be programmed to lock out if seven faults are detected within a 30 min window.

Lockout is also useful in preventing a circuit interrupting device from inadvertently autoreclosing when it is closed manually into a faulted line. The lockout condition is automatically reset after the breaker is closed manually, either locally or remotely, and remains closed for a preset period of time ~~in case so that~~ a fault does not exist at the time of breaker closure.

4.6 Autoreclosing supervision

Various forms of autoreclose supervision have been applied to autoreclosing. These include elements such as bus and line voltage monitoring, synchronism check, transfer trip signals, and parallel line supervision.

Autoreclose supervision serves such purposes as preventing autoreclosing when systems are out of synchronism, preventing autoreclosing that might cause damage to generators or motors, minimizing the number of unsuccessful autoreclosings, preventing autoreclosing into faulted equipment such as transformers and reactors, and helping maintain system stability.

The most commonly used methods for autoreclose supervision are discussed in 4.6.1 through 4.6.6.

~~Synchronism check relays can be used where analysis shows that for credible system conditions there could be harmful effects on the system, generators, or customers due to excessive differences in frequencies, phase angles, or voltage magnitudes across the closing breaker. When applying synchronism check relays, appropriate consideration should be given to avoiding unnecessary restriction of breaker autoreclosing or manual closing following major system disturbances. It may, however, be necessary to use means to prevent undesired autoreclosing modes from occurring.~~

4.6.1 Voltage supervision

Voltage supervision of autoreclosing allows for verification that voltages on both sides of a breaker are of a desired magnitude prior to autoreclosing. The voltage supervision relay monitors either a single-phase voltage or three-phase voltages, depending on system configuration and/or line connections. ~~the system conditions to be checked before autoreclosing and can improve system restoration times.~~ Types of voltage supervision that could be applied are as follows:

- a) Dead-line/[dead-bus](#).
- b) Live-bus/dead-line (also known as “hot-bus/dead-line” or “HBDL”).
- c) Live-[bus/live](#)-line (also known as “hot-[bus/hot](#)-line”). [For this scenario, consideration is also given to sync check supervision \(refer to 4.6.2 and 6.3.7\).](#)
- d) Live-line/dead-bus (also known as “hot-line/dead-bus” or “HLDB”). [This scenario is applicable to lines originating from a ring bus.](#)

~~The voltage supervision would monitor either a single phase voltage or three phase voltages, depending on system configuration and/or line connections.~~

~~The following are typical elements, application examples, and considerations for autoreclose supervision. Applications will vary depending on particular system configurations and utility practices.~~

[In the majority of cases,](#) voltage monitoring serves to supervise autoreclosing for live-bus/dead-line or live-[bus/live](#)-line conditions. It [allows for leader-follower](#) ~~enables lead/follow-end~~ autoreclosing where the [leader terminal](#) ~~lead-end~~ autorecloses first on dead-line (zero or very low voltage) conditions and the [follower terminal](#) ~~follow-end~~ autorecloses after the line is successfully re-energized (when the line voltage is normal). While [monitoring a single](#) ~~one relay connected to one~~ phase of ~~a line~~ [side voltage terminal](#) may be [sufficient](#), ~~sufficient for voltage monitoring~~ ~~three relays~~ ~~(one-per -phase)~~ [line voltage monitoring is sometimes](#) ~~may be~~ applied to provide ~~for~~ added reliability [in detection of a hot line. This is especially valuable in cases where a generator or large decelerating motor is islanded with the line following a breaker trip.](#) It ~~may~~ ~~should~~ also be noted that particularly for high-voltage transmission lines with line reactors, the [stored energy resonating between the line capacitance and inductance \(reactors\)](#) ~~trapped charge~~ is expected to maintain near rated voltage for a considerable time following a single line-to-ground fault operation. This voltage decays with the natural frequency of the line and reactors. This ~~may~~ ~~should~~ be considered in the application of voltage monitoring relays.

4.6.1.1 Considerations for voltage supervision ~~for~~ **of** autoreclosing

Autoreclosing is often supervised by voltage. ~~The permissives. These~~ voltage supervision can ~~permissives often~~ use ~~only~~ a single potential, connected phase-to-neutral (or occasionally phase-to-phase). If a line has tapped terminals and these terminals can back-feed the line, the main terminal re-energizing the protected line may ~~should~~ be supervised by dead-line voltage sensing. Voltage supervision allows for the time delays of the reclosing relay to be decreased. Without voltage supervision, autoreclosing is normally ~~should be~~ delayed long enough to permit all terminals to clear the fault.

A method to confirm that all three phase voltages for autoreclosing supervision are proper is to use three single phase-to-ground voltage transformers connected grounded wye-grounded wye (care is ~~should be~~ taken to avoid ferroresonance or overvoltage to these voltage transformers when back fed from a delta winding) or two phase-to-phase voltage transformers connected open delta-open delta. If only one voltage transformer connected single phase-to-ground is employed, then proper voltage sensing may not occur, especially if a source of back-feed exists and is connected via a delta-connected transformer. If a single phase-to-ground fault exists with back-feed from such a source and single-phase sensing was utilized, two phases may have high voltage and one phase low or zero. Thus, if dead-line voltage supervision was used, the autoreclosing could occur in error. A single phase-to-phase connected voltage transformer could possibly be used if the source of back-feed did not use independent pole operated circuit breakers. If the unmonitored phase did not open properly, the autoreclosing could occur in error. Also, failure of the voltage supply by a blown fuse or other defect could cause autoreclosing in error. Therefore, sensing could be by two relays connected to different phases, or dropout of a single relay could be monitored or alarmed.

Under stressed operating conditions, the voltage on some energized portions of the system may vary significantly from nominal. Depending on the voltage thresholds used to detect live or dead conditions, undesired reclosing may occur. For example, if a line is energized at 0.75 per unit voltage, live-bus/dead-line reclosing may occur (even though the line is energized) if the threshold for sensing the line dead is greater than 0.75 per unit. When reclosing relays are applied with adjustable voltage threshold settings for determining whether system elements are live or dead, consideration to the thresholds selected is necessary to ~~reduce~~ ~~minimize~~ the risk of unintended and potentially undesirable reclosing attempts.

Live-bus and live-line voltage detectors ~~may~~ ~~should~~ be set at or below the lowest system voltage for which automatic reclosing is deemed desirable on a stressed system. A setting in the vicinity of 0.8 per unit is appropriate and not unusual.

Dead-bus and dead-line detectors ~~are~~ ~~should be~~ set ~~as low as possible~~, but also ~~should be~~ set high enough to verify that a disconnected element is determined to be dead even in the presence of trapped charge on a cable or capacitor bank or induced voltage from a parallel transmission line in the same right-of-way. Dead-line reclosing voltage supervision is typically set as low as 0.2 or 0.3 per unit for a single-circuit line, but in some cases (such as parallel circuits) the setting may ~~by virtue~~ ~~need to~~ be significantly higher.

If voltage supervision is not applied correctly, the anti-pump scheme of a breaker may be defeated. For example, upon breaker trip, reclosing relay sends a close command with a dwell time of a half second. Typically, voltage supervision permissive contact, i.e., dead line detector, is in series with the close contact of a reclosing relay. Upon confirmation of a dead line by voltage supervision relay, the breaker closes. Even if a fault is still present, voltage supervision relay may drop out by detecting voltage on an unfaulted phase. This opens the close circuit and resets the breaker anti-pump control logic. The breaker trips again due to a fault and a voltage supervision relay gives permission, i.e., declares dead-line. As the reclosing relay is continuing to hold close command due to a dwell time of a half second, breaker closes again. The voltage supervision relay drops out by detecting a voltage on an unfaulted phase and resets the breaker anti-pump control logic. Breaker trips due to a permanent fault. This process continues until a close command is removed or breaker fails. There are number of ways to address this issue. One is to remove the close command immediately upon sensing of breaker closure. An alternative is to add a pickup delay to the voltage supervision relay, i.e., permission is given after a brief time delay.

~~It is important to recognize that considerations for setting live and dead voltage detectors, including personnel safety, equipment protection, reclosing under desirable conditions, and preventing reclosing under undesirable conditions, may lead to conflicting criteria. When this occurs, it should be clear that protecting personnel and equipment have the highest priority.~~

4.6.2 Synchronism-check supervision

Synchronism check is applied to supervise autoreclosing when there is a realistic possibility of an excessive phase angle, frequency difference (slip), or voltage magnitude across the breaker contacts to be closed. The excessive differences in frequencies, phase angles, or voltage magnitude across the closing breaker could have a harmful effect on the system, generators, or customer equipment. When applying synchronism-check relays, appropriate consideration is given to avoiding unnecessary restriction of breaker autoreclosing or manual closing following major system disturbances. It may, however, be necessary to use a means to prevent undesired autoreclosing from occurring.

The setting of the synchronism check function is based on the differences between the two voltages and is designed to ~~reduce~~ ~~minimize~~ the impact to the system when the breaker is closed. When studies or actual system events identify lines that are subject to tripping during system separation, consideration ~~may~~ ~~should~~ be given to adding synchronism check even if it is deemed unnecessary for normal operating conditions, since preventing undesired live-bus/live-line autoreclosing during out-of-step conditions may avert damage to generating and substation equipment.

4.6.3 Transfer trip supervision

Transfer trip supervision of autoreclosing allows for verification of a system configuration prior to autoreclosing. ~~Receipt of Transfer trip signal.~~ Lines that have transformers or reactors connected without a breaker ~~are~~ ~~should~~ not ~~be~~ autoreclosed for faults in those devices until it can be assured that the faulted transformer or reactor has been isolated. This autoreclosing can be supervised by receipt of a transfer trip signal from the remote terminal. This transfer trip signal can also be applied to block autoreclosing if there has been a breaker failure operation at the remote terminal. Where the transfer trip function is also part of the line protection, such as in a permissive overreaching transfer trip scheme, it is necessary to distinguish between a transfer trip received for a communication-assisted line relay operation, which would permit autoreclosing, and a transformer, reactor, or breaker failure operation, which would not initiate autoreclosing. This can be accomplished by time discrimination. If the transfer trip signal is received for longer than the normal clearing time, autoreclosing is blocked. Alternatively, separate transfer trip signals could be used; one for the communications-assisted line protection, and a separate transfer trip signal for the transformer, reactor, or breaker failure transfer trip function.

4.6.4 Parallel line supervision

Parallel line current supervision can serve to block autoreclosing where a parallel line is out of service and there is concern with autoreclosing out of synchronism. These current elements ~~are~~ ~~typically~~ ~~should be~~ set above the line charging current.

4.6.5 Supervision for high-speed reclosing

~~Typical autoreclose monitoring applications:~~ For high-speed autoreclosing (typically less than 1 s), utilities often elect not to monitor the autoreclosing since autoreclosing is generally fast enough that the synchronizing angle changes very little during the open period, or parallel ties will verify synchronism. However, some utilities apply a degree of high-speed monitoring with high-speed autoreclosing. For example, the designated lead terminal could autoreclose with no supervision with the follow terminal set to autoreclose only after voltage has been restored on all three phases. There is very little time difference in closing time between the two terminals since reclosing relay timing is initiated by tripping. In some cases, parallel line current supervision could also be applicable for high-speed autoreclosing.

4.6.6 Autoreclose supervision following automatic load shed trip

Underfrequency ~~Automatic~~ load shedding (UFLS) is performed ~~quickly~~ to arrest power system frequency decline by decreasing the connected load in order to match available generation. Undervoltage ~~The matching of~~ load shedding (UVLS) is performed in a similar function to UFLS, but uses voltage as a system indicator instead of frequency. The process ~~and generation~~ is achieved by tripping feeder breakers ~~feeders~~ or reclosers ~~lines~~. Autoreclosing is typically blocked during UFLS and UVLS events.

Provided that ~~When~~ the system returns to a normal state, the tripped load can ~~could~~ be restored either manually or automatically. If ~~via~~ automatic reclosing methods are used for load restoration, then parameters within the automatic schemes, like voltage, time, and ~~methods. In many regions,~~ ~~manual restoration is preferred. However, it would be possible to configure~~ frequency supervision, are considered in order to prevent an additional load shed event during the restoration process. Due to the wide variation of systems and their load demands, detailed system studies are beneficial to assist with selecting autoreclosing methods to use following load shed events ~~in reclosing devices to autoreclose feeders tripped by UFLS.~~

4.7 Autoreclose blocking

There are several conditions for which blocking of autoreclosing is desirable. The most commonly used methods to block autoreclose and reasons are discussed in this subclause.

4.7.1 Drive to lockout

The autoreclosing is generally ~~typically~~ blocked and driven to lockout for ~~under the~~ following conditions ~~scenarios~~:

- Manual or SCADA trip of a circuit breaker: As previously discussed, ~~trips,~~ autoreclosing is blocked if the breaker is opened manually at the station or remotely via SCADA ~~by remote~~ control. When a breaker is opened in this manner, the reclosing function is driven to lockout since it is desirable that the operation of the breaker remains in hands of the person that opened the breaker. This means that if the breaker trips immediately after it is closed the breaker will not reclose automatically since it has not gone through its reset cycle. This feature is generally part of switching on to fault protection ~~it is desirable that it be under operator control for closure.~~
- Voltage unbalance:- Autoreclosing can be blocked if a voltage unbalance condition is detected at the station. A source-side open phase can cause such unbalances. Restoring service under unbalanced conditions could cause damage to customer equipment, so it may be desirable to block autoreclosing function and drive to lockout for this condition.
- b) ~~Line side voltage supervision. Autoreclosing can be blocked if voltage exists on the line. Such supervision is usually provided if large motors, generators, or other sustained sources are connected to the line. Autoreclosing is blocked if these downstream sources are maintaining voltage on the line in order to prevent possible damage to the associated rotating equipment due to being energized out of phase or to the establishment of an undesirable system operating condition. (See 4.5.1 and 4.7.8.)~~

- e) ~~Faults on buses, transformers, or underground cables. These faults are most likely permanent in nature, and autoreclosing a breaker could aggravate electrical equipment damage. Consider the risks and benefits of autoreclosing versus blocking all autoreclosing.~~
- Breaker failure to trip: When a breaker fails to trip, protection. Breaker failure protection typically trips all breakers or at least all source breakers directly connected to the same bus, are tripped and reclosing on these breakers is blocked not only to clear directly or through the fault but also to isolate bus differential protection. Restoration of the bus is usually under an established procedure that includes isolation of the failed breaker. Driving the other bus breakers to lockout limits the damage and limits the remaining system's exposure to any additional faults while in this compromised condition Autoreclosing of the healthy breakers is blocked until the failed breaker is isolated and the bus is restored.
- Breaker failure to close: If an attempt is made to autoreclose, and the breaker does not close (based on 52 auxiliary contact) or fails to close within the expected close time, or if a discontinuity (open circuit) is detected, then further attempts to autoreclose are blocked.
- Trip circuit monitor: Autoreclosing can be blocked if a discontinuity (open circuit) in trip circuit is detected.
- High-current faults: A high-set instantaneous element can be used to block autoreclosing for close-in, high-magnitude faults. This type of blocking is typically applied where these faults are likely to be permanent ~~or~~ in the substation equipment or exit cables, or exceed the damage rating of the source transformer or other equipment.
- Cumulative operations: Where an entity keeps track of a breaker's health by keeping up lockout. Used in locations with the fault duty approaching adjusted circuit breaker rating to block autoreclosing after a predetermined number of breaker operations and possibly the fault energy the breaker is subjected to, the entity may choose to drive the reclosing function to lockout until inspection and necessary maintenance can be performed.

- Receipt of transfer trip: ~~When~~ During the receipt of a transfer trip signal represents a failed breaker at the remote terminal, a common practice is to block reclosing and drive the reclosing function to lockout. In some schemes, a timer is initiated by the receipt of the transfer trip signal. If this timer times out, only then ~~operation of~~ the reclosing function is driven to lockout ~~sequence is prevented~~.
- Distance protection overreach zone ~~3~~ or time delayed backup tripping: An overreaching distance zone used for providing backup tripping can be configured to disable reclosing, since a trip by this zone indicates a protection failure in a different zone. When high-speed communication assisted protection schemes are used to obtain high-speed tripping, a time delayed trip indicates a failure of a protection system component and some utilities prefer to block further reclosing under such a condition.
- Three-phase faults: As previously discussed in 4.4.1, other conditions for which reclosing may be blocked and driven to lockout include a three-phase fault occurring ~~faults are rare~~ on extra high voltage transmission lines where it is highly indicative of a permanent fault ~~EHV (345 kV and above)~~ and ~~therefore are~~ unlikely to result in a successful reclose ~~be of a temporary nature~~. These faults most often result from ground straps left in place after breaker maintenance or downed line structures. A three-phase fault is the most severe from the system stability perspective as the voltage on all three phases is impacted. Under certain system conditions, reclosing into a permanent three phase fault may result in system instability and if so, reclosing is not desirable. For example, reclosing into a permanent three-phase fault may result in a loss of synchronism of nearby generating units when transmission line(s) in the close vicinity are out or when the system load is below a certain level. ~~therefore, blocking of autoreclosing could be considered.~~ Since temporary three-phase faults are more probable for lower voltage transmission lines, autoreclosing may be desirable if system stability and generation are not negatively affected.
- Automatic load shedding (underfrequency or undervoltage): Distribution lines ~~Feeders~~ tripped by automatic load shedding typically have autoreclosing blocked. This is done to allow the system operator to determine when an outaged feeder can be restored to service based on system conditions.

- ~~Power swing and~~ Out of step tripping: Out ~~conditions. On detection of a power swing or~~ ~~out-of-step~~ tripping is typically implemented at predetermined locations to separate two systems that are losing synchronism due to system instability. Autoreclosing is typically ~~condition, autoreclosing should be~~ blocked, because an autoreclose ~~autoreclosure~~ could further agitate an already disturbed system condition. ~~This action should be taken whether~~ ~~the out-of-step or power swing relay is used to block tripping or initiate stripping of the~~ ~~breaker.~~

4.7.2 Delayed reclose

Another form of autoreclose blocking includes delayed reclosing. Examples of these are discussed in 4.4.1 (understanding selective reclosing logic) and 4.6 (autoreclosing supervision). In each of these reclosing schemes, the reclosing function is simply delayed until the desired system condition is met. However, in many autoreclosing schemes, if desired system conditions are not met within a predefined time, reclosing is typically driven to lockout.

Subclause 4.7.1 discussed conditions when it is appropriate to drive reclosing to lockout for a receipt of a transfer trip signal; however, there may be situations where it might simply be necessary to temporarily block reclosing to allow other actions to take place. For example, when an autotransformer is connected on a transmission line, via a motor operated air switch, a transfer trip scheme is generally applied. For this situation, when a transfer trip signal is received reclosing is generally blocked until the trip signal is removed. The trip signal is generally supervised by an 89a contact of the air switch. When the trip signal is removed indicating that the air switch has opened and the faulted autotransformer is isolated from the line, the autoreclose block is removed.

4.7.3 Stall reclose

The stall feature is used to block reclosing by delaying reclosing until the trip signal is removed. This prevents reclosing on a permanently sealed trip signal and allows coordination with other relays such as an electromechanical time overcurrent relay that may be slow to reset. When sync check supervision is used, reclosing is stalled to allow voltages on either side of the open breaker to come within the predefined sync check parameters.