

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

IEEE Power & Energy Society

Sponsored by the  
Power System Relaying Committee



---

IEEE  
3 Park Avenue  
New York, NY 10016-5997  
USA

6 July 2012

IEEE Std C37.104™-2012  
(Revision of  
IEEE Std C37.104-2002)



**This is a Redline Document produced by Techstreet, a business of Thomson Reuters.**

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 fastpaced 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.

## Redline Processing Notes:

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

# **IEEE Guide for Automatic Reclosing of Circuit Breakers for AC Distribution and Transmission Lines**

Sponsor

**Power System Relaying Committee**  
of the  
**IEEE Power & Energy Society**

Approved 8 June 2012

**IEEE-SA Standards Board**

**Abstract:** Current reclosing practices for transmission and distribution lines are described. Application considerations and coordination practices of reclosing are also discussed.

**Keywords:** automatic operation, circuit breaker, distribution, IEEE C37.104, reclosing, transmission

---

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

Copyright © 2012 by The Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 6 July 2012. 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 978-0-7381-7293-4 STD97268  
Print: ISBN 978-0-7381-7345-0 STDPD97268

IEEE prohibits discrimination, harassment, and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/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.

**Notice and Disclaimer of Liability Concerning the Use of IEEE 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 a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. 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.

Use of an IEEE Standard is wholly voluntary. IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon any IEEE Standard document.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained in its standards is free from patent infringement. IEEE Standards documents are supplied "AS IS."

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. Every IEEE standard is subjected to review at least every ten years. When a document is more than ten 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 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.

**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 should be considered 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 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 his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

**Comments on Standards:** Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide 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 to ensure 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. Any person who would like to participate in evaluating comments or revisions to an IEEE standard is welcome to join the relevant IEEE working group at <http://standards.ieee.org/develop/wg/>.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board  
445 Hoes Lane  
Piscataway, NJ 08854  
USA

**Photocopies:** Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

## Notice to users

## 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 imply 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.

## Copyrights

This document is copyrighted by the IEEE. It is made available 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 this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

## Updating of IEEE 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. 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 the IEEE-SA Website at <http://standards.ieee.org/index.html> or contact the IEEE at the address listed previously. For more information about the IEEE Standards Association or the IEEE standards development process, visit IEEE-SA Website at <http://standards.ieee.org/index.html>.

## Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

## Patents

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 <http://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 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.

## Participants

At the time this IEEE guide was completed, the D2 Working Group had the following membership:

**Gary L. Kobet, *Chair***  
**Gregory Sessler, *Vice Chair***

George Bartok  
Kenneth Behrendt  
Dean Bender  
Martin Best  
Albert N. Darlington  
Alla Deronja  
Dominick Fontana  
Fredric Friend  
Robert Frye  
Gerald Johnson  
Meyer Kao

Don Lukach  
Bruce Mackie  
Walter McCannon  
Michael Meisinger  
Adi Mulawarman  
Pratap Mysore  
James O'Brien  
Russ Patterson  
Claire Patti  
Joe Perez

Ryland Revelle  
Tony Seegers  
Bill Strang  
Charles Sufana  
Philip Tatro  
Quintin Verzosa  
Ilia Voloh  
John Wang  
Phil Waudby  
Thomas Wiedman  
Richard Young

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

William Ackerman  
Satish Aggarwal  
Ali Al Awazi  
Steven Alexanderson  
George Bartok  
David Bassett  
Philip Beaumont  
Kenneth Behrendt  
Steven Bezner  
Stan Billings  
Wallace Binder  
Kenneth Birt  
Thomas Blackburn  
Chris Brooks  
Gustavo Brunello  
Eldridge Byron  
Paul Cardinal  
Stephen Conrad  
James Cornelison  
Randall Crellin  
Randall Cunico  
Kevin Donahoe  
Gary Donner  
Michael Dood  
Ahmed Elneweihi  
Gary Engmann  
Dan Evans  
Marcel Fortin  
Fredric Friend  
Doaa Galal  
Rafael Garcia  
David Gilmer  
Mietek Glinkowski  
Jalal Gohari  
Stephen Grier  
Randall Groves  
Wayne Hartmann

Roger Hedding  
Jerry Hohn  
David Horvath  
Joseph Jancauskas  
Gerald Johnson  
Gael Kennedy  
Yuri Khersonsky  
James Kinney  
Gary L. Kobet  
Joseph L. Koepfinger  
Jim Kulchisky  
Chung-Yiu Lam  
Raluca Lascu  
Albert Livshitz  
Federico Lopez  
Greg Luri  
Bruce Mackie  
William McBride  
Walter McCannon  
Michael McDonald  
Nigel McQuin  
Steven Meiners  
Michael Meisinger  
Dean Miller  
Adi Mulawarman  
Jerry Murphy  
R. Murphy  
Arthur Neubauer  
Michael S. Newman  
Joe Nims  
James O'Brien  
Ted Olsen  
Mohamed Omran  
Lorraine Padden  
Mirko Palazzo  
Donald Parker  
Christopher Petrola

Robert Pettigrew  
Farnoosh Rahmatian  
Moises Ramos  
Ryland Revelle  
Michael Roberts  
Charles Rogers  
Bob Saint  
Miriam Sanders  
Bartien Sayogo  
Thomas Schossig  
Tony Seegers  
Gregory Sessler  
Devki Sharma  
Gil Shultz  
James Smith  
Jerry Smith  
Joshua Smith  
Gary Stodter  
Charles Sufana  
James Swank  
Michael Swearingen  
Richard Taylor  
William Taylor  
Maria Tomica  
Demetrios Tziouvaras  
Eric Udren  
John Vergis  
Quintin Verzosa  
Ilia Voloh  
John Wang  
Solveig Ward  
Yingli Wen  
Kenneth White  
Thomas Wiedman  
Philip Winston  
Richard Young  
Jian Yu

When the IEEE-SA Standards Board approved this guide on 8 June 2012, it had the following membership:

**Richard H. Hulett**, *Chair*  
**John Kulick**, *Vice Chair*  
**Robert M. Grow**, *Past Chair*

Satish Aggarwal  
Masayuki Ariyoshi  
Peter Balma  
William Bartley  
Ted Burse  
Clint Chaplin  
Wael Diab  
Jean-Philippe Faure

Alexander Gelman  
Paul Houzé  
Jim Hughes  
Young Kyun Kim  
Joseph L. Koepfinger\*  
John Kulick  
David J. Law  
Thomas Lee  
Hung Ling

Oleg Logvinov  
Ted Olsen  
Gary Robinson  
Jon Walter Rosdahl  
Mike Seavey  
Yatin Trivedi  
Phil Winston  
Yu Yuan

\*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*  
Michael Janezic, *NIST Representative*

Julie Alessi  
*IEEE Standards Program Manager, Document Development*

Soo H. Kim  
*IEEE Client Services Manager, Professional Services*

## Introduction

This introduction is not part of IEEE Std C37.104-2012, IEEE Guide for Automatic Reclosing of Circuit Breakers for AC Distribution and Transmission Lines.

The art and science of protective relaying for the automatic reclosing of circuit breakers associated with distribution and transmission lines following the clearing of a fault have evolved over many years. This guide is an effort to compile information on the application considerations associated with this practice. The guide presents generally accepted practices for autoreclosing. Its purpose is to describe the methods and considerations associated with situations in which it is desirable to reclose automatically. It is intended for engineers who have a basic knowledge of power system protection. This is an application guide and does not cover all of the requirements for autoreclosing for every situation or protection scheme. Additional reading material is suggested so that the reader can evaluate the application of autoreclosing for the individual situation.

## Contents

|                                                                                    |    |
|------------------------------------------------------------------------------------|----|
| 1. Overview .....                                                                  | 1  |
| 1.1 Scope .....                                                                    | 1  |
| 1.2 Purpose .....                                                                  | 1  |
| 2. Normative references.....                                                       | 2  |
| 3. Definitions .....                                                               | 2  |
| 4. Fundamentals and applications.....                                              | 3  |
| 4.1 The autoreclosing function performed by a reclosing relay.....                 | 4  |
| 4.2 Autoreclosing nomenclature.....                                                | 5  |
| 4.3 Autoreclosing circuitry and logic .....                                        | 6  |
| 4.4 Autoreclosing settings .....                                                   | 9  |
| 4.5 Autoreclosing supervision .....                                                | 10 |
| 4.6 Autoreclose blocking.....                                                      | 12 |
| 4.7 Application considerations .....                                               | 13 |
| 4.8 Substation controller.....                                                     | 19 |
| 4.9 SCADA.....                                                                     | 19 |
| 5. Autoreclosing for distribution systems.....                                     | 19 |
| 5.1 Distribution system overview .....                                             | 19 |
| 5.2 Distribution autoreclosing practices .....                                     | 20 |
| 5.3 Autoreclosing coordination practices .....                                     | 21 |
| 5.4 Application considerations .....                                               | 25 |
| 6. Autoreclosing for transmission systems .....                                    | 26 |
| 6.1 Transmission systems overview .....                                            | 26 |
| 6.2 Autoreclosing methods .....                                                    | 27 |
| 6.3 Application considerations .....                                               | 30 |
| 7. New technologies/special applications .....                                     | 44 |
| 7.1 Ethernet based applications to autoreclosing .....                             | 44 |
| 7.2 Coordination of fast valving and high-speed reclosing .....                    | 45 |
| 7.3 Sychrophasor applications .....                                                | 46 |
| 7.4 Autoreclosing (load restoration) after underfrequency load shedding.....       | 46 |
| 7.5 Point-on-wave (POW) and staggered pole autoreclosing .....                     | 47 |
| 7.6 Multi-Phase Autoreclosing (MPAR) .....                                         | 47 |
| 7.7 Pulseclosing .....                                                             | 49 |
| Annex A (informative) Bibliography .....                                           | 50 |
| Annex B (informative) History of automatic reclosing.....                          | 56 |
| Annex C (informative) Sample method to indicate autoreclosing mode and timing..... | 58 |
| Annex D (informative) Index .....                                                  | 61 |

# IEEE Guide for Automatic Reclosing of ~~Line~~ 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

~~The purpose of~~ This guide documents present practices regarding ~~is to establish guidelines for~~ the application of automatic reclosing control facilities to line circuit breakers. 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.

~~This guide describes current automatic reclosing practices for ac distribution and transmission lines. Included within this description are application considerations and coordination practices for reclosing.~~

## 1.2 Purpose

The guide provides benefits of automatic reclosing and provides application considerations for proper coordination with other system controls (e.g., autosectionalizing, 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.

~~Automatic reclosing can restore or facilitate restoration of the system to normal, following automatic tripping of distribution and transmission facilities. Throughout this guide, the shorter term "autoreclosing" will be used in place of *automatic reclosing*. Italicized terms are defined in Clause 3 of this guide.~~

~~Autoreclosing may be applied for the purpose of restoring distribution and transmission lines to service subsequent to automatic tripping of their associated circuit breakers due to electrical faults. Experience indicates that many faults on the overhead power system are temporary. In the absence of autoreclosing, longer duration outages could be experienced unnecessarily. Successful autoreclosing can enhance stability margins and overall system reliability. However, autoreclosing into a permanent fault can adversely affect system stability, damage equipment, or have adverse effects on customers; hence, due consideration shall be given to this aspect of any application. See Annex B for a brief history of automatic reclosing.~~

## 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.

~~This guide shall be used in conjunction with the following publications. When the following publications are superseded by an approved revision, the revision shall apply.~~

IEEE Std ~~ANSI~~ C37.06<sup>TM</sup> IEEE ~~-2000, American National~~ Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities<sup>1</sup> for Voltages Above 1000 V.<sup>1,2</sup>

IEEE Std C37.04<sup>TM</sup>~~-1999~~, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers.

IEEE Std C37.60<sup>TM</sup>~~-1981 (Reaff 1992)~~, IEEE Standard Requirements for Overhead, Pad Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems.

~~<sup>1</sup>ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10038 (<http://www.ansi.org>).~~

<sup>1</sup> The IEEE standards or products referred to in this clause are trademarks ~~of~~ owned by The Institute of Electrical and Electronics Engineers, Inc.

<sup>2</sup> IEEE publications are available from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, ~~P.O. Box 1331~~, Piscataway, NJ 08854~~5-1331~~, USA (<http://standards.ieee.org/>).

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.

~~IEEE Std C37.61™ -1973 (Reaff 1992), IEEE Standard Guide for Application, Operation, and Maintenance of Automatic Circuit Reclosers.~~

### 3. Definitions

For the purposes of this document ~~guide~~, the following terms and definitions apply. The IEEE 100™ [B6] Standards Dictionary Online should be consulted ~~referenced~~ for terms not defined in this clause.<sup>3</sup>

~~NOTE—Those terms marked with an asterisk (\*) are also listed in IEEE 100 [B6].~~

**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.

<sup>3</sup>IEEE Standards Dictionary Online subscription is available at [http://www.ieee.org/portal/innovate/products/standard/standards\\_dictionary.html](http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html).

**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 a circuit breaker in order to restore an element to service following automatic tripping of 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.

**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 circuit breaker is open and the controlled circuit is de-energized following the tripping operation for a fault and before the autoreclosing attempt.\*

**delayed autoreclosing:** Refers to the autoreclosing of a circuit breaker after 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:** Refers to the autoreclosing of a circuit breaker after a necessary time delay to permit fault arc deionization 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 wherein the controlled line breaker is open and the relay disabled from making any further reclose attempts.\*

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

**multiple-shot autoreclosing:** Refers to the autoreclosing of the circuit breaker(s) more than once within a predetermined autoreclosing sequence.

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

**reclosing relay:** Programmable relay whose function is to initiate the automatic reclosing of a circuit breaker.

**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 a circuit breaker following a designed single-phase trip for single-phase-to-ground faults.\* Also referred to as single-phase autoreclosing.

**sync check:** See also: synchronism check

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

**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.\*

## 4. Fundamentals and applications

### 4.1 ~~Basics~~

This clause describes fundamental concepts common to automatic reclosing for both transmission and distribution line breakers. 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, and automatic reclosing can be used to quickly re-energize the line to restore system integrity, service to customers, or both. However, as discussed, circuit breakers may also be automatically reclosed following a relay initiated bus trip, again where there is a good possibility that the fault was temporary and automatic reclosing will speed restoration of the bus and system integrity.

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 or remote-manual control. To apply autoreclosing properly, several factors should be considered ~~addressed~~. Some of the most common considerations ~~frequently asked fundamental questions~~ are as follows:

- a) What is the probability of successfully reclosing the ~~faulted~~ 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?
- 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, what terminal of the line should be selected as the lead reclosing terminal?
- j) How should autoreclosing be initiated?

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

## 4.1 The autoreclosing function performed by a reclosing relay

The autoreclosing function has traditionally been performed by a reclosing relay that is dedicated to a specific circuit breaker. However, the autoreclosing function can be performed by any number of devices or processes that get an input to identify when the circuit breaker 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 computers, and even supervisory control and data acquisition (SCADA) systems have been used to perform the autoreclosing function. Most microprocessor-based transmission line and distribution feeder protective relays 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.

The autoreclosing function can be considered to be in one of four distinct states:

- 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.

- Cycle state: The circuit breaker is open and the autoreclose function is timing toward its set time to close the circuit breaker, OR, the circuit breaker is closed following a successful autoreclose, timing toward its set time to return to the 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 open and locked out, meaning that the circuit breaker must now be closed by some other means (local-manual or remote-manual).
- Power-up state: May be used in some autoreclosing relays when the relay is powered up. In this state, the autoreclose relay assesses its inputs to determine the state of the breaker and the autoreclose initiate and supervision inputs. After assessing these inputs, the autoreclose relay typically changes to the 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 reset state, the autoreclosing function can be initiated in one of two ways to start timing toward its 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
- 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 initial autoreclose attempt. This transition to timing toward the first autoreclose attempt changes the reclose function from the reset state to the 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 may go to lockout, releasing the close output, or continue to assert the close output, depending on the reclosing relay design and programming. When the breaker closes, ~~At this point,~~ 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 relay continues timing toward reset. At the completion of the reset time delay, the autoreclosing function returns to the reset state and remains there as long as the breaker is still closed.

If ~~the illustrated sequence,~~ 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 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 reset state. ~~and initiates closing of the breaker.~~

If the fault is permanent ~~persists~~ and the number of programmed/set autoreclosing attempts expires, the reclosing relay advances to the lockout state, leaving the breaker open. The autoreclosing function ~~relay~~ is now “locked out” ~~disabled~~ until the breaker is closed by other means. 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 from the lockout condition. In the event that the breaker is manually closed and fails to remain closed, ~~care should be taken in the~~ reclosing relay circuitry/logic 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. If the reset time delay is less than the tripping time delay, a breaker pumping condition can occur which may ultimately lead to breaker damage, system equipment damage, and possible public hazard.

## 4.2 Autoreclosing **Timing** nomenclature

There are many autoreclosing relay designs in service today. Electromechanical, solid state, and microprocessor-based autoreclosing relays or 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, an autoreclosing relay may have an inherent time delay of 0.2 s, whereas another 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, when it will actually have a reclose time of 0.2 s because of the 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 this is construed by others to mean that the relay 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 relays are set with a reclosing delay setting of 0.2 s for consistency, the relay with virtually no inherent time delay will issue its breaker close command 0.2 s faster than the relay with the inherent delay, possibly leading to damaged motors or generators that are re-energized before their isolating devices had a chance to operate.

~~One other fundamental concern deals with timing nomenclature. A problem occurs with how the autoreclosing times are indicated. Various utilities may indicate the same autoreclosing sequence but in different ways that can lead to misunderstandings between them. For example (using the basic symbol R to indicate one autoreclosing shot):~~

~~One utility may not indicate a time if the inherent time of the reclosing relay is used. For example, if the inherent time delay were 0.2 s, then this utility would indicate the autoreclosing mode as R.~~

~~However, settings from another utility may use R0.2. Confusion could arise as to whether this means an autoreclosing time of 0.2 s or 0.4 s. For the purpose of this guide, the notation R0.2 indicates a setting of 0.2 s in addition to any internal delay of the relay.~~

Additional confusion can arise in how multiple autoreclosing shots are indicated. For example, a two-shot autoreclosing may be described as ~~R<sub>15</sub>R<sub>30</sub>~~ 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 reclose initiation. In the second interpretation, this means the second attempt occurs 30 s after reclose initiation.

Some 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 circuits to coordinate fast and delayed curve tripping between series connected protective devices.

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 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.

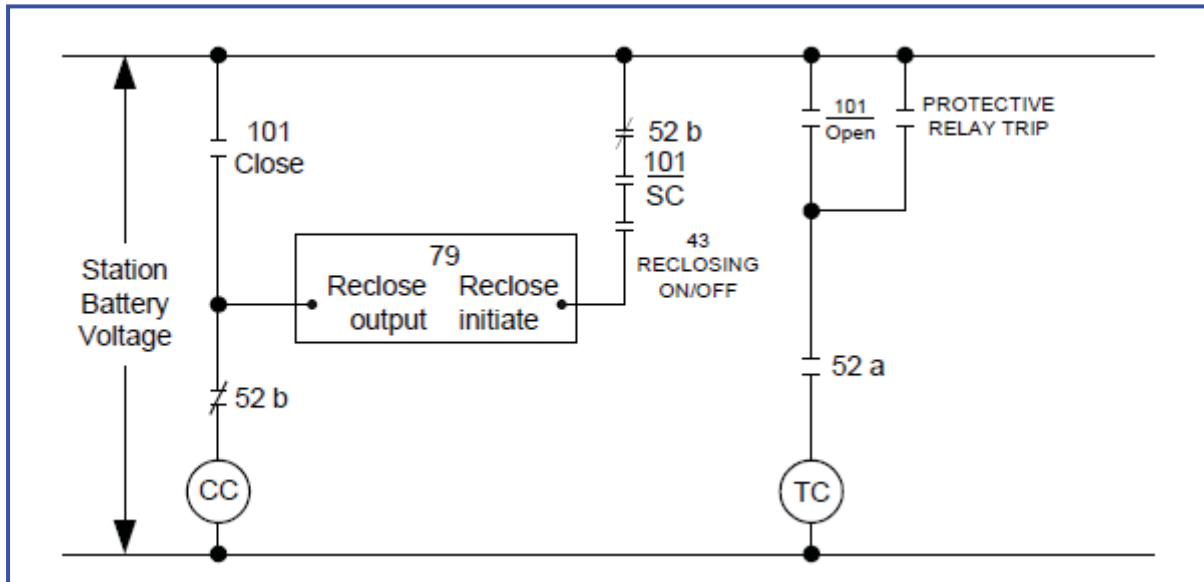
## 4.3 Autoreclosing circuitry and logic ~~permissives~~

### 4.3.1 ~~General~~

Autoreclosing is initiated either by the transition of a circuit breaker auxiliary contact on breaker opening or by protective relay trip, and possibly ~~but not~~ both. ~~When a recloser is substituted in a substation for a feeder circuit breaker, the IEEE recloser standards and codes should be used for application (IEEE Std C37.60-1981; IEEE Std C37.61-1973).~~ Control circuitry or logic is required so to ensure that circuit breakers autoreclose only when intended. The control circuitry/logic is different depending on the type of autoreclose initiation required by the 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 needed to distinguish between a local-manual control switch or remote control trip, and a protective relay trip, since autoreclosing is not desired for a local-manual or remote trip.

One technique used to prevent autoreclosing of local-manual trips is to install ~~then~~ a slip contact of the circuit breaker control switch ~~is installed~~ in series with the reclosing relay close initiation input. 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. ~~A control switch OFF contact should be added to this circuit such that an instantaneous autoreclosure is not enabled until after a successful manual reclosure and the control switch is released.~~ This series 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. ~~Protective relay circuits, when properly designed, operate only during a fault. Autoreclosing should not be initiated by protective relays when the breaker is opened manually. Autoreclosing is initiated by the closure, then opening of protective relays' contacts, signifying that a fault has occurred. This operation cycle signifies that a fault was interrupted and autoreclosing can now proceed~~

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.<sup>4</sup>



(New)

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

<sup>4</sup> Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

Figure 1 illustrates a simplified control circuit with autoreclosing. Contacts shown in the figure include:

- 101: Manual breaker control switch
- 101/Close: Contact closed when control handle turned to CLOSE position, contact open when control handle turned to TRIP position and in the normal-after-close and normal-after-trip position
- 101/Open: Contact closed when control handle turned to TRIP position, contact open when control handle turned to CLOSE position and in the normal-after-close and normal-after-trip position
- 101/SC: Contact closed when control handle turned to CLOSE position and in the normal-after-close position, contact open when control handle turned to TRIP position 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

~~It may be desirable that a time delay be used when restoring the autoreclosing function when the circuit breaker is manually closed. Some reclosing relay and control circuit designs disable the reclosing relay for a manual operation of the circuit breaker by setting the reclosing relay to the “locked out” condition. When enabling the autoreclosing function, these relays can be caused to wait for the period of the reset time delay within the relay. This feature, sometimes referred to as switch onto fault, is used to ensure that if the breaker were closed into a permanent fault, then the reclosing relay would not be initiated and attempt its programmed number of operations prior to locking out.~~

~~Another timing circuit can disable autoreclosing if autoreclosing permissives are not satisfied within the prescribed time interval. For example, for dead line autoreclosing, if the line voltage does not drop to zero (less than the setting of the undervoltage element) on all monitored phases within a time interval after the reclosing relay is initiated, usually 30 s, then autoreclosing is disabled. This prevents unexpected autoreclose operations later when the permissive condition is satisfied. For autoreclose initiation by protective relay, if the protective relay does not reset within the prescribed time interval, then autoreclosing is also disabled.~~

#### 4.3.1 Understanding 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:

— 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
- High-speed reclosing for pilot scheme/communications-assisted tripping, and delayed 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 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. ~~There are a large variety of schemes used today.~~ Some schemes only initiate autoreclosing for ~~on~~ pilot (communication assisted) trips where it is likely that a similar pilot trip will occur if the fault re-establishes on autoreclose. Others avoid ~~only block (or fail to initiate)~~ autoreclosing for conditions such as multiphase faults where system stability is of concern, time-delayed trips where pilot is used, when out-of-step tripping is used, or where sensitive or critical loads can be affected. ~~Almost any element of the microprocessor relay can now be used in site specific schemes.~~

Autoreclose blocking can be similarly applied by initiating reclosing relay operation for any breaker trip and using blocking logic to stop and reset reclose relay operation, or block the reclose relay close output if the breaker is tripped manually, either locally or remotely. The blocking logic may be more complicated because it must operate before the first reclose time occurs and because the reclosing relay must be allowed to run to lockout before the block is removed. Failure to verify that the reclose relay is in the lockout or reset state before removing the block can result in unexpected and undesired breaker closing operations, so simply halting reclose relay operation is not an option.

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 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 breaker closing at a much later time.

When applying selective autoreclosing, one should bear in mind that faults are often dynamic in nature. The probability of autoreclosing into unacceptable conditions needs to be weighed against the likelihood of the fault not reigniting and therefore re-establishing the circuit in a timely manner. ~~In addition,~~ Some microprocessor algorithms may not always properly identify the fault type, which could unnecessarily prevent proper autoreclosing, or allow autoreclosing when not intended vice-versa.

### 4.3.2 Understanding of device internal logic and processing

To design reclosing controls using microprocessor relays, the designer should first understand how, and in what order, the relay processes the programmable logic. Since every element and word bit in the relay cannot be scanned and processed simultaneously, the relay 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 refer to the 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.

## 4.4 Autoreclosing settings

### 4.4.1 Number of reclosing attempts **operations**

Single-shot autoreclosing is the autoreclosing of a circuit breaker 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 more than one time in a predetermined autoreclosing sequence. Multiple-shot autoreclosing systems should be designed considering available air or gas pressure for breaker operation, system stability, potential equipment damage due to excessive current or heating, and potential adverse effects to customers and their equipment.

## 4.4.2 Dead time

### 6.2.1.1 Deionizing 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, ~~a certain interval of time is required to ensure that the path of the arc is sufficiently deionized so that the fault does not re-establish itself on closing~~, an autoreclose attempt without sufficient time delay to allow the dielectric to re-establish its strength results in an unsuccessful reclose attempt event.

The ionized-gas 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 (Westinghouse Electric Corporation [B103]).<sup>5</sup> An example of ~~Under normal conditions~~, a good minimum delay is given by ~~established using~~ Equation (1) for deionization of air at the fault location:

$$t = 10.5 + V_{L-L} / 34.5 \quad (1)$$

Where  $t$  is time expressed in cycles, and  $V_{L-L}$  is rated line-to-line voltage (kV).

For some other types of circuit breakers, a delay 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.

The arc deionization time can increase if a nearby adjacent parallel line helps to sustain the arc or if single-phase pole tripping is used and the energized phases sustain the arc. ~~Frequently, with oil circuit breakers, the minimum closing time of the circuit breaker exceeds this deionization time.~~

<sup>5</sup> The numbers in brackets correspond to those of the bibliography in Annex A.

### 4.4.3 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 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 will reduce ~~Even if the autoreclosing is successful, the reclosing relay is not rearmed until the reset time delay expires. This lessens~~ the possibility of excessive tripping and autoreclosing for intermittent faults. A delay shorter than the duration between intermittent faults 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 undesirable lockout operations.

If the autoreclosure is not successful, the relay moves to a lockout position so that the interrupting device cannot be automatically closed. Autoreclosing is ~~also~~ locked out, or terminated, after the programmed number of attempts to reenergize the line are tried and unsuccessfully completed. The lockout 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 ~~distribution feeder, which can be caused by wind, tree contact, or lightning during storm conditions.~~

Some ~~Modern~~ 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 so that a fault does not exist at the time of breaker closure.

## 4.5 Autoreclosing supervision

### 6.2.2.2 Phase angle, frequency, and voltage considerations

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.

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](#) ~~ensure~~ undesired autoreclosing modes [from occurring](#) ~~do not take place~~.

Voltage supervision of autoreclosing allows for the system conditions to be checked before autoreclosing and can improve system restoration times. Types of voltage supervision that could be applied are:

a) Dead-line

b) Live-bus/dead-line ([also known as “hot-bus/dead-line”](#))

c) Live-line ([also known as “hot-line”](#))

d) Live-line/dead-bus ([also known as “hot-line/dead-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 ~~requirements and~~ utility practices.

- 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 setting of the synchronism check function is based on the differences between the two voltages and is designed to 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 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.](#)

- Receipt of transfer trip signal. Lines that have transformers or reactors connected without a breaker should not be autoreclosed for faults in those devices ~~the equipment~~ 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, ~~then~~ 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.
- Voltage monitoring serves to supervise autoreclosing for live-bus/dead-line or live-line conditions. It enables lead/follow end autoreclosing where the lead end autorecloses first on dead-line (zero or very low voltage) conditions and the follow end autorecloses after the line is successfully re-energized (when the line voltage is normal). ~~It can also serve to protect against undue energizing and damage to generators and motors.~~ While one relay connected to one phase of a line terminal may be sufficient for voltage monitoring, ~~many utilities elect to~~ three relays (one per phase) may be applied to provide for added reliability. It should also be noted that particularly for high-voltage transmission lines with line reactors, ~~after a line tripout on a~~ the 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 should be considered in the application of voltage monitoring relays.

- 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. ~~Note that~~ These current elements should be set above the line charging current.
- 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.

~~With delayed autoreclosing (autoreclose time typically more than 1 s) only one terminal of a transmission line is usually autoreclosed at a time and it is typical practice to make extensive use of voltage monitoring. For example, after a fault tripout the lead terminal autoreclose timing can start on loss of line potential. This ensures that the other terminal has tripped. The following terminal's autoreclose timing starts if there has been a loss of potential followed by a restoration of potential. If there are insufficient or weak parallel ties to assure that synchronism is maintained during the dead period, the following end's autoreclosing can be monitored by a synchronism check relay.~~

### 4.5.1 Voltage supervision of autoreclosing

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

A method to ~~confirm~~<sup>ensure</sup> 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 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 ~~occurred~~ with back-feed from such a source and single phase sensing was utilized, ~~then~~ two phases may have high voltage and one phase low or ~~almost at~~ zero. Thus, if dead-line voltage supervision was used, ~~then~~ 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 minimize the risk of unintended and potentially undesirable reclosing attempts.

Live-bus and live-line voltage detectors 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 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 need to be significantly higher.

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 Autoreclose blocking

Autoreclosing is typically blocked under the following scenarios:

- a) Manual trips. Autoreclosing is blocked if the breaker is opened manually at the station or by remote control. When a breaker is opened in this manner, it is desirable that it be under operator control for closure.
- 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.)

~~b) Bus faults. Autoreclosing of lines can be blocked for bus faults. (See 5.2.4 and 5.3.5 for possible exceptions.)~~

- c) 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.
- d) 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.
- e) Breaker failure protection. Breaker failure protection typically trips all breakers connected to the bus directly or through the bus differential protection. Restoration of the bus is usually under an **established** procedure that includes isolation of the failed breaker. Autoreclosing of the healthy breakers is blocked until the failed breaker is isolated and the bus is restored.
- f) 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.
- ~~i) Hot line maintenance. Improve safety by disabling autoreclosing while line crews perform hot line maintenance.~~
- g) 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.
- h) Cumulative operations lockout. Used in locations with fault duty approaching adjusted circuit breaker rating to block autoreclosing after a predetermined number of operations until inspection and necessary maintenance can be performed.

- i) Receipt of transfer trip. During the receipt of a transfer trip signal. In some schemes, a timer is initiated by the receipt of the transfer trip signal. If this timer times out, operation of the reclosing sequence is prevented.
- j) Zone 3 or backup tripping. An overreaching distance zone used for backup tripping can be configured to disable reclosing, since a trip by this zone indicates a protection failure in a different zone.
- k) Automatic load shedding (underfrequency or undervoltage). Feeders tripped by automatic load shedding typically have autoreclosing blocked.
- ~~k) Breaker failure to trip or trip circuit monitor alarm. If a relay trip has occurred, but the breaker stays closed longer than the expected breaker trip time (e.g., 6-10 cycles), block autoreclosing and initiate tripping of the backup breaker. Also, if trip circuit logic is available, then use this logic to block autoreclose if an open trip circuit is detected.~~

## 4.7 Application considerations

### 4.7.1 Lines with underground cables

Faults involving underground cables are often permanent, and ~~the use of~~ autoreclosing should be applied ~~used~~ within the guidelines of the following paragraphs. ~~Distribution~~ Lines that utilize underground cables for a portion of their total length present a special concern for utilities as to whether or not to incorporate autoreclosing.

If the line is completely cable, ~~it makes no sense to~~ autoreclosing should not be attempted. ~~into a permanent fault.~~ There is no need to subject the cable to ~~more importantly the customer to~~ additional damage and subject the circuit breaker, bus, and substation transformer and adjacent portions of the power system to additional stress and potential damage. Therefore, the use of autoreclosing on lines ~~feeders~~ entirely made of cable is not recommended as per IEEE Power System Relaying Committee Report [B50].

Depending on the location and length of the cable section relative to the total line length, some utilities consider this type of feeder as totally overhead and apply their standard autoreclosing practice. Others consider a single shot of autoreclosing to test the line for a temporary fault or other condition that could have caused the relay to misoperate. Another solution could be the use of sectionalizing to isolate the cable section together with a modified autoreclosing scheme.

If the line is partially cable and partially overhead, autoreclosing could be used if a determination can be made that the fault is not in the cable portion (Sufana et al. [B95]). ~~utility is willing to risk additional damage to the cable. Lines that experience a temporary fault on the overhead section that could be successfully cleared would benefit from the use of autoreclosing. If the fault were to occur in the cable portion, then the substation equipment and line would sustain further damage from the autoreclose attempt. If the cable portion of the line is where the feeder leaves the substation and goes a short distance to the overhead portion, then it could be possible to incorporate a relay scheme (perhaps by the use of a high set instantaneous overcurrent element) that will determine if the fault is inside the cable and abort the autoreclose attempt.~~

~~If the cable portion of the distribution feeder is located "out in the middle," then the use of autoreclosing may not be prudent. If expense were not a problem, it would be possible to install relaying (i.e., current differential, pilot wire, or phase comparison) on the cable portion to determine if the fault was in the cable and inhibit autoreclosing. This approach would be expensive, as there would be a need for a communication channel and additional current transformers.~~

It is also important to keep in mind as to which end of a hybrid line is to close in first for an autoreclosing attempt. Transient overvoltage studies using a transient network analyzer may need to be performed to identify any problems that could occur if the line is autoreclosed. These studies are especially important if a shunt inductor is added to the line as a means to control the voltage boost effect due to the cable capacitance (Sufana et al. [B95] and Truax et al. [B99]).

#### 4.7.2 Autoreclosing following Distribution bus faults

Automatic reclosing after a bus fault is sometimes used to restore the system to normal operation. The decision to employ automatic reclosing after a bus fault is based on the trade-off between the impact of an extended bus outage versus the consequences of reclosing into a bus fault. Since power system buses generally terminate multiple elements, the impact of a bus fault and consequent bus outage can have a significant impact on the security and operability of the system. The benefits of automatically restoring a bus following a temporary fault are typically weighed carefully against the risks should the fault in fact be permanent, such as system stability factors and possible damage to primary equipment, transformers and turbine generators in particular.

For open-air type substations, autoreclosing on the bus breaker is sometimes performed when protective relays operate for faults on the bus. The autoreclose is generally time-delayed (e.g., 5 s) and not supervised except for buses that can be fed from another source. These other sources could be dispersed generation on the lines, tie breakers that normally run closed, or feeds from other transformers. In these cases, the autoreclose may be supervised by an undervoltage relay. Other system conditions could also require blocking the autoreclose, such as breaker failure, transformer differential, or underfrequency trip.

A bus that primarily uses open-air as the insulation medium is subject to faults from foreign objects, lightning, small animals, flashover of dirty insulators, and so on in much the same manner as any overhead transmission or distribution line. An example of this type of bus is an outdoor open rigid bus or open strain bus. If these types of faults are promptly cleared, there is some probability that reclosing without inspection will be successful. Bus conductor spacing, a function of bus voltage, can greatly impact this probability. Animal contact for instance, typically temporary in nature, is more likely at distribution voltages than transmission.

Because open-air buses are routinely protected from public exposure by substation fencing or other barriers, one might argue that the public safety risk associated with automatically reclosing for a bus fault is significantly lower than that of an overhead line. However, there are additional risks to maintenance or construction personnel who are within the fenced area due to the application of automatic reclosing for bus faults. This additional risk can be reduced by use of a reclose cutoff function to block autoreclosing when work is in progress, in much the same manner as the “live-line maintenance” feature typically used on distribution and transmission circuits.

A bus may be insulated so as to provide physical protection to the bus from outside interference. Examples of this type of bus are insulated cable, isolated phase bus, buses in metal-clad switchgear, SF<sub>6</sub> switchgear, and so on. A fault on a bus with this type of insulation is usually not self-clearing. For this reason, automatic reclosing of breakers is not likely to be successful for this type of bus.

If automatic reclosing is employed for bus faults, one of the breakers connected to the bus can be equipped with a single-shot reclosing relay to reclose the breaker for a dead-bus-live-line condition. It is a common practice to select a breaker for the task of testing the bus that will have the least impact to the system if the fault is permanent. Usually it is the live circuit with the least short-circuit capacity. However, the bus differential relay is required to be sensitive to the reduced fault level to permit tripping in case of a permanent fault. This can be achieved by lowering the pickup threshold on bus de-energization and for a short period of time following, or using a simple instantaneous overcurrent function associated with the reclosing relay. Typically, when deciding on the sensitivity of bus protection when reclosing, one takes into account the inrush current created by VTs and similar equipment permanently connected to the bus.

If reclosing of the first breaker is successful, the remaining breakers on the bus can be reclosed with automatic reclosing relays programmed to close the breakers for a live-bus condition provided other system conditions permit.

### 4.7.3 Circuit breakers

#### **6.2.1.2 Minimum reclosing time**

All circuit breaker mechanisms and interrupters require a minimum time between the initiation of the tripping action and the initiation of the ~~autore~~ reclosing operation. This time allows for the dielectric within the breaker to stabilize to a point where the breaker will be able to interrupt a fault again on reclose. These times should be defined by the manufacturer. If this minimum time requirement is not incorporated into the breaker design, ~~a time delay could be required within~~ the reclosing relay dead time should be greater than this limiting time of the breaker ~~When there is a question regarding this feature, the breaker manufacturer should be consulted.~~

Another consideration is the time it takes for the breaker's stored energy mechanism to recharge following each trip. If the reclosing intervals are too short, the stored energy system, e.g., spring or compressed air, may not recharge sufficiently to allow a subsequent trip. If this happens, the breaker mechanism may employ an interlock scheme to prevent breaker closing until sufficient stored energy is available to permit a breaker trip.

These capability factors are defined in the standards for oil and air magnetic circuit breaker technologies where the time between short-circuit current interruptions is critical to allow the dielectric to recover strength within the interrupter of the circuit breaker. These derating factors may not be required for technologies such as SF<sub>6</sub> puffer or vacuum circuit breakers, as the dielectric recovery time is less than the open-interval ~~operating time of the circuit breaker between operations~~. However, the manufacturer should be consulted whenever the autoreclosing duty cycle of the breaker differs from the standards. Oil circuit breaker interrupting capabilities depend on the reclosing sequence and the fault magnitude.

Circuit breakers are required to have an interrupting capability rating based on the Rated Standard Operating Duty (standard duty cycle). The standard duty cycle, as defined by IEEE Std C37.04-~~1999~~, is two operations with a time interval of 15 s between operations [CO (close – open) + 15 s + CO]. Whenever the autoreclosing duty cycle characteristic is set for more than two operations, or the time interval between operations is less than 15 s, the interrupting capability rating on the circuit breaker is modified. An autoreclosing duty cycle could incorporate one or both of these characteristics, effectively reducing or derating the interrupting rating. This derating for autoreclosing is necessary to allow for the dielectric recovery of the insulating medium in the circuit breaker following arc extinction.

#### 4.7.4 Effects of autoreclosing on disk type overcurrent relays (ratcheting or notching)

~~As mentioned in 5.2.2,~~ Electromechanical disk type time overcurrent relays respond to current above their pickup level in a time inversely proportional to the current level. When the current level is above the pickup, the disk begins to turn and continues to turn until the rotating contact meets the stationary contact to cause a breaker trip or until the current drops below the pickup level, as would occur if the fault were cleared by downstream protection. Disk reset will occur when the current has dropped below the pickup level for a period of time. The disk resets to its original position at a relatively slow rate by the action of a coil spring. This relatively slow reset action of the disk should be taken into consideration when autoreclosing is applied to any breaker or circuit recloser downstream of this breaker.

The most common application that requires special care is the circuit recloser operating to clear sections of a feeder downstream of a circuit breaker having disk type overcurrent relays applied. The circuit recloser can autoreclose the faulted section multiple times, resulting in several periods of fault current flow through both the circuit recloser and the upstream circuit breaker. In a coordinated system, the circuit recloser trips and removes the fault current flow before the disk type overcurrent relays reach their trip point. A minimum safety margin is normally provided ~~for to assure~~ good coordination. At the point the overcurrent condition is removed, the disk has rotated some percentage of the amount required to provide a trip.

If the disk is not fully reset by the time the circuit recloser operates to re-energize the faulted section, the disk will not have as far to travel as during the original fault. This ratcheting effect could lead to a loss of coordination resulting in the unnecessary tripping of the circuit breaker.