

IEEE Guide for Breaker Failure Protection of Power Circuit Breakers

IEEE Power and Energy Society

Sponsored by the
Power System Relaying Committee

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USA

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Power System Relaying Committee
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IEEE Power and Energy Society

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Abstract: Methods to protect a power system from faults that are not cleared because of failure of a power circuit breaker to operate or interrupt when called upon by a protective relay are described in this guide. The intent is to give the reader a guide in how to detect that a breaker has failed to clear a fault, and how to electrically isolate the fault after the breaker has failed to clear the fault. Additionally, schemes that provide primary protection of the power system from performance failures of the power circuit breaker other than fault clearing failures such as failure to operate, either tripping or closing, manual or automatic, are also described. Such schemes, when applied, are typically integrated as a part of the overall breaker failure protection scheme. Also covered are recent practices that take advantage of new technologies.

Keywords: BFP, breaker failure, breaker failure protection, circuit breaker, fault, IEEE C37.119™, power system

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Introduction

This introduction is not part of IEEE Std C37.119-2016, IEEE Guide for Breaker Failure Protection of Power Circuit Breakers.

This guide is a revision to IEEE Std C37.119-2005. Corrections to timing diagrams describing particular schemes have been made to improve clarity and accuracy. Precautionary statements have been added to provide guidance based upon occurrence of recent power system events.

The definition and scope of breaker failure protection has been broadened to provide a more comprehensive description of breaker failure protection, not only for power circuit breakers applied to transmission lines but also for generator unit breakers. In addition to breaker failure initiation for fault conditions, initiation from automatic or manual tripping and closing devices that detect potentially damaging non-fault conditions is now included.

In addition to the breaker failure logic schemes previously provided by the guide, examples of best practices of how to interconnect control power to redundant protective relay systems while providing breaker failure functionality is provided. These methods increase the independence of the primary protection from the local backup protection and thereby decrease the impact of single points of failure within the overall protection scheme. Practical considerations are now included that describe application of breaker failure protection to legacy equipment and modern microprocessor relays, and that describe the interaction of the breaker failure protection scheme with local and remote controls including automatic reclosing, lockout, and restoration functions.

Other additions to the guide include descriptions for column ground fault protection, breaker differential protection, and tandem breaker protection. These protection functions are typically applied as a part of the overall breaker failure protection scheme.

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1. Overview

1.1 General

Breaker failure protection (BFP) is a backup protection for the power system that is needed when a power circuit breaker fails to clear a fault when called upon to do so by a protective relay. The BFP scheme acts to isolate the fault from the protected power system by removing from service power circuit elements located electrically adjacent to the failed power circuit breaker.

In general, backup relay protection has been used on power systems for many years. Typically, all parts of the protection system including the relays, voltage and current transformers, circuit breakers, and control power source are vulnerable to failure. All of these components are needed to work properly to effectively clear a fault. To improve protection system reliability, components such as protective relays, power sources, and instrument transformers are often duplicated. Duplicate systems are designed to operate independently to ensure complete protection system functionality during failures. Because it is usually too costly to duplicate the breaker, breaker failure schemes are specifically employed to provide backup protection in the event that a circuit breaker fails to operate properly during fault clearing.

Primary protection of the power system from performance failures of the power circuit breaker other than fault clearing failures is sometimes added to breaker failure schemes. These include failure to operate, either tripping or closing, manual or automatic. Where applied, this protection typically exists as an addition to, and as a part of, the same overall scheme as the breaker failure backup protection.

The choice and successful application of any BFP scheme depends upon factors such as the local breaker arrangement and also the relative criticality of protected power circuit elements. There is a delicate balance

between the risk of damage to unprotected equipment versus the impact of removing adjacent power circuit elements when the scheme operates.

This guide reviews generally accepted breaker failure schemes used on utility transmission and generation systems. Many of the characteristics of these schemes also apply to the use of breaker failure on utility distribution systems. Schemes are carefully examined so that advantages as well as disadvantages can be compared. Application examples and testing practices are also included.

The guide is written for engineers who have a working knowledge of power system protection but require a better understanding of breaker failure applications. It can also be used as an evaluation tool when comparing alternative breaker failure options.

1.2 Scope

This guide describes methods to protect a power system from faults that are not cleared because of failure of a power circuit breaker to operate or interrupt when called upon by a protective relay. The intent is to give the reader a guide in how to detect that a breaker has failed to clear a fault, and how to electrically isolate the fault after the breaker has failed to clear the fault. Additionally, schemes that provide primary protection of the power system from performance failures of the power circuit breaker other than fault clearing failures such as failure to operate, either tripping or closing, manual or automatic, are also described. Such schemes, when applied, are typically integrated as a part of the overall BFP scheme. Also covered are recent practices that take advantage of new technologies.

1.3 Purpose

This guide is intended to help the relay engineer understand the application considerations when applying BFP to power circuit breakers.

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 C37.102™, IEEE Guide for AC Generator Protection.^{1, 2}

IEEE Std C37.113™, IEEE Guide for Protective Relay Applications to Transmission Lines.

3. Definitions, acronyms, and abbreviations

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3.1 Definitions

backup protection: A protection scheme for the same zone of protection as the primary protection but may be slower and removes the same or additional equipment from service. Backup protection may be installed locally, i.e., in the same substation as the primary protection, or remotely.

breaker failure protection (BFP): A form of protection that is designed to detect the failure of a circuit breaker to operate or to interrupt a fault. Upon detection of a breaker failure during a fault condition the scheme is designed to take appropriate action to clear the fault. Upon detection of a breaker failure during a non-fault condition, the scheme may take other appropriate action.

control timer: A timer that limits the amount of time the breaker failure scheme is active after initiation. This is a time delay on pickup timer.

common-mode failure: A multiple failure attributable to a common cause.

critical clearing time: The longest time that fault conditions may persist before system stability is lost.

local backup protection: A backup protection system that is in the same substation as the primary protection. However, it may use some of the same equipment, such as transducers, batteries, and circuit breakers as the primary protection and can therefore fail to operate for the same reasons as the primary protection.

primary protection: The main protection system for a given zone of protection that operates in the fastest time and removes the least amount of equipment from service.

remote backup protection: Historically, the first set of backup protection that was installed. It is completely independent of the relays, transducers, batteries, and circuit breakers of the primary protection system it is backing up by virtue of its physical location. Its advantage is that there are no common-mode failures that can affect both systems of protection. Its disadvantage is the fact that remote protection may remove more system elements than is desirable or necessary to clear a fault. Additionally, as the power system matured, it became increasingly difficult for remote protection to detect (see) all the faults that the primary protection could detect.

3.2 Acronyms and abbreviations

The following are a listing of abbreviations used in this guide:

50	instantaneous overcurrent element
50G	instantaneous overcurrent ground element
50P	instantaneous overcurrent phase element
50BF	breaker failure current detector
52a	breaker auxiliary contact that is closed when the breaker is closed and open when the breaker is open

⁴It is recognized that these definitions are only intended to facilitate communication so that there is general understanding of the subject under discussion. They are not to be rigidly applied as if they constituted design specifications. Protection systems are designed in accordance with accepted engineering principles involving reliability (dependability and security), selectivity, and coordination. The definitions when applied to individual elements, or to the total protection system, are for specific applications and may vary with the application. For instance, in a substation without a pilot protection system, time-delay overcurrent or zone 2 relays are the primary protection for faults in the last 10% to 20% of the line but are the remote backup protection for the adjoining bus and line section. When a pilot scheme is installed, the time-delay overcurrent and zone 2 relays are then referred to as local backup for the end-of-line faults and remote backup for the adjoining bus and line section.

52b	breaker auxiliary contact that is open when the breaker is closed and closed when the breaker is open
52aa	breaker auxiliary contact that is closed when the breaker is closed, and opens as soon as the breaker operate mechanism begins moving from the closed to the open position
62	breaker failure timer, time delay on pickup
86BF	breaker failure auxiliary lockout relay
94	auxiliary tripping relay
BFI	breaker failure initiate
BFP	breaker failure protection
BFR	breaker failure relay
CT	current transformer
CTR	current transformer ratio
DTT	direct transfer trip
DUTT	direct underreaching transfer trip
EHV	extra-high voltage
IED	intelligent electronic device
LAN	local area network
SCADA	supervisory control and data acquisition
WAN	wide area network

4. Need for breaker failure protection

Circuit breakers are strategically located in power systems to connect circuits and electrical apparatus. Circuit breakers are commanded to open and close by protection and control systems that monitor conditions on the power system. Protective relay systems detect abnormal conditions, most notably, system faults (short circuits), and direct one or more circuit breakers to open in order to isolate the faulted circuit or equipment. Protection systems are coordinated so that the circuit breaker(s) nearest the fault are opened to interrupt or clear the fault with minimum impact to the remainder of the power system. This critical operation requires that the circuit breaker interrupt, or clear, fault current.

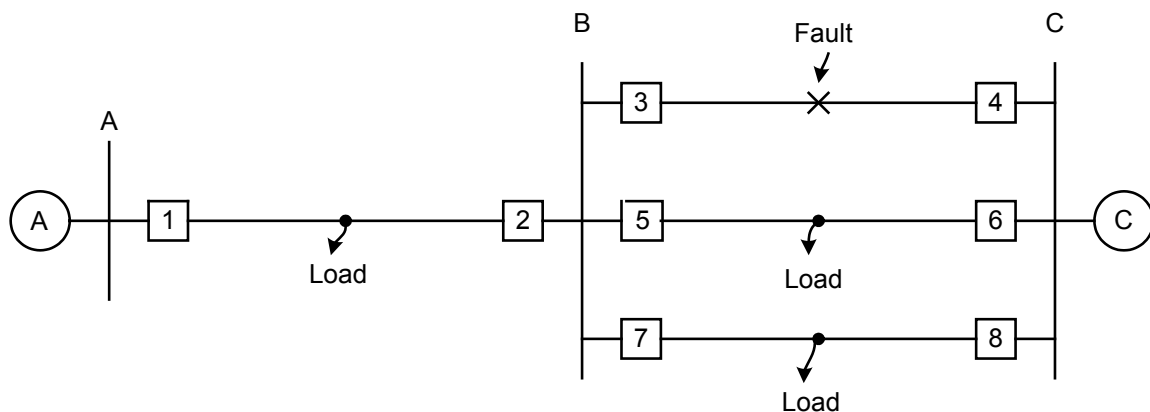


Figure 1—Local and remote breaker clearing

While infrequent, circuit breakers occasionally fail to trip, or fail to clear a fault. Depending on the power system network topology, other circuit breakers are then called upon to trip and isolate the sources contributing to the fault. Referring to [Figure 1](#), assume a fault exists between breaker 3 and breaker 4. Protective relays associated with breaker 3 and breaker 4, designed to detect faults on the line between these breakers, operate and command breaker 3 and breaker 4 to trip. In this example, breaker 3 fails to interrupt the fault current. Therefore, all sources that continue to supply fault current through breaker 3 need to be interrupted. Assuming sources at stations A and C, breakers 2, 5, and 7 need to be opened locally, or breakers 1, 6, and 8 would need to be opened remotely.

To implement remote breaker failure backup protection for breaker 3, the protective relays at breakers 1, 6, and 8 have overreaching elements that sense faults anywhere on the line between breaker 3 and breaker 4, and operate after a time delay, typically about 0.5 s to 1.0 s.⁵ This time delay is required to allow time for the local line protection on breaker 3 to operate, and for the breaker to successfully clear the fault, recognizing that the local protective relay scheme on breaker 3 may include time delayed tripping to coordinate with other protective relays. Remote backup protection does not have the benefit of knowing exactly when the breaker is commanded to open. Therefore, the remote backup protection needs to have sufficient time delay to accommodate all possible tripping delays.

Local BFP, on the other hand, receives a signal directly from the line protection relays at the same station as the impaired breaker, indicating when the trip command is sent to the breaker. The local BFP only needs to wait for the breaker to successfully clear the fault, typically only 0.1 s to 0.2 s. If local BFP for breaker 3 detects a breaker failure, it commands adjacent local breakers 2, 5, and 7 to trip to clear the fault. In many cases, if a direct transfer trip (DTT) protection channel is available, it will also command the remote breaker 4 to trip and lockout. Of course, for a fault on the line between breaker 3 and 4, breaker 4 would have been tripped by the line protection relays. But, sending DTT will prevent a manual or automatic reclose of breaker 4.

Remote backup, therefore, has the following disadvantages:

- All tapped loads between breakers 1–2, 5–6, and 7–8 are dropped causing widespread customer outages.
- The lengthy backup clearing time will cause excessive system voltage dip duration, additional damage to faulted equipment, possible damage to unfaulted equipment, and may lead to system instability.
- Due to infeed effects from the other lines, it may be difficult to set the remote relays at 1, 6, and 8 to detect faults on the entire length of the adjacent lines.
- The settings required to provide sufficient reach to detect faults out to the remote ends of the adjacent lines may be so sensitive that the line is susceptible to tripping under heavy load during extreme disturbances, which could initiate or exacerbate a wide-area cascading outage.

The advantage of remote BFP is that it is completely independent of protective relays, control systems, and battery supplies at the station with the failed breaker.

An alternative to remote backup is local backup, and its subset breaker failure relaying. Local BFP eliminates the disadvantages of remote backup protection. Using the example in [Figure 1](#) again, and concentrating on breaker 3, when the protective relay on breaker 3 senses a fault on line 3–4 and issues a trip to breaker 3, local BFP starts a timer. If the timer times out, and the fault is not cleared by breaker 3, then the local breaker failure scheme sends trip signals to adjacent breakers 2, 5, and 7. The local breaker failure scheme has several benefits over the remote backup scheme. If there are sources at buses A and C,

⁵Throughout this document, where seconds or milliseconds are used as units to describe intentional protection system coordination delays and/or timer settings, a power system operating at 60 Hz is assumed unless otherwise described.

tapped loads between breakers 1–2, 5–6, and 7–8 can still be served. The total clearing time for the fault is reduced substantially compared to the remote backup method. The timer setting for the local breaker failure scheme is composed of breaker interrupting time plus some margin. Margins may range from less than 0.0167 s to 0.050 s (1 cycle to 3 cycles) as dictated by the critical fault clearing time. Protective relay time is not included in this time delay. This timer setting is typically less than 0.200 s (12 cycles), compared to 0.5 s to 1.0 s (30 cycles to 60 cycles or more if the tripping has to happen sequentially) for remote backup. This time difference could mean the difference between a stable and unstable system for some critical faults and may substantially reduce the extent of damage at the fault, through fault stress on equipment, and effect of voltage depressions on adjacent loads.

The primary disadvantage of local BFP is that it may suffer from common-mode failure. Station battery failure, for example, that may be the original cause of the breaker failure condition, may also disable the local BFP. Likewise, local protective relay malfunction may cause a failure to trip the breaker and also fail to initiate the local breaker failure timer. For this reason, redundant protective relay systems for each zone are also often coupled with local BFP systems in a component failure tolerant protection system. Otherwise, failure to detect a fault and failure to interrupt a fault are considered as the same contingency that requires backup by overreaching relays tripping different breakers (remote backup). The cost of adding BFP systems, while once a major consideration, has been significantly reduced as the breaker failure function has been integrated into modern microprocessor-based protective relay schemes.

There are many things that may cause the failure of a circuit breaker to interrupt fault current. Many are external to the breaker such as a loss of tripping power, dc battery failure, battery charger failure, dc breaker tripped or blown fuse, loose wire or shorted trip circuit, etc. If one of these is the cause for the failure, slow clearing of the fault will probably not cause further damage to the breaker. However, some common causes for the failure to interrupt are that the breaker mechanism travel is incomplete or the mechanism is slow; components needed for the interruption: (resistors or capacitors), are faulty; or the dielectric material in the interrupter is out of specification (low pressure, low temperature) or contaminated. If these are the causes for the failure to interrupt, the breaker needs protection to prevent further damage. By the time the remote backup protection has operated, the arcing inside the interrupter will likely cause a phase-to-ground fault internal to the breaker. These internal faults may lead to explosions and fires. As a result of the slow clearing of the original fault, what could have been a minor breaker repair project, if the faulty breaker had been isolated in a timely manner, now may require the replacement of the breaker and possibly other equipment in close proximity to the faulty breaker.

To summarize, when considering if BFP systems will be applied, the following three fundamental attributes of the protection system need to be considered:

- Sensitivity: Can the overreaching protective relays in adjacent zones reliably detect faults in 100% of the zones to be backed up, considering infeed?
- Selectivity: Is it acceptable to trip additional power system elements and loads that may be otherwise preserved by applying a BFP system?
- Speed: Is delayed clearing from remote backup for a breaker failure event acceptable for system stability, power quality, equipment through-fault stress, and equipment fault damage?

One final consideration in deciding to rely solely on remote backup is the cost and effort of relay setting maintenance. The analysis effort required for an even moderately complex networked system to consider all possible system configurations and current distributions that affect infeed for all possible breaker failure scenarios is difficult. Assuming that the analysis has been performed adequately, even small changes to the network may require that all of this effort be repeated to prove that remote backup can be relied upon.

For further information about remote backup, refer to IEEE Std C37.113.

5. Breaker failure modes

BFP is designed to operate when the protective relaying scheme initiates a circuit breaker trip and that breaker does not interrupt the fault. BFP will be considered a subset of local backup protection. Breaker failure can be caused by a variety of situations, as follows:

- Failure to Trip: In failure to trip situations, the breaker contacts do not open after the trip circuit has been energized by the protective scheme. This could be caused by an open or short in the trip circuit wiring or in the trip coil. It could also be the result of a mechanical problem in the breaker that prevents the contacts from opening; this condition is also known as “stuck breaker.”
- Failure to Clear: In these scenarios, the breaker contacts open, but the arc is not extinguished and current continues to flow. This could be caused by mechanical problems (incomplete opening), or dielectric problems (such as contaminated oil or loss of vacuum). Failure to clear is significantly different from failure to trip in that the breaker auxiliary contacts (52a and 52b) will change state, which indicates breaker opening. Because of this, an auxiliary contact position may not be a reliable indicator of a satisfactory breaker opening.

Another failure to clear mode can occur in breakers with opening resistors. In this mode the resistor insertion contact operates successfully, but the main contacts fail. This results in a high impedance to current flow, but does not interrupt the flow of current.

Both breaker failure modes can occur during high-current and low-current faults, including transfer trip from remote locations.

There are also situations where a circuit breaker operates incorrectly, but is not classified as a breaker failure. These situations (as follows) are considered in system design, and may be incorporated within the breaker failure protective scheme:

- Loss of dielectric during non-fault conditions can prevent satisfactory interruption of current if called upon, potentially leading to a true breaker failure. Loss of dielectric pressure can be detected in SF6 breakers using a gas density or pressure monitor. For loss of pressure below a cutoff point, breaker manufacturers typically recommend blocking the breaker tripping to prevent mechanical or electrical failure. In this case, the breaker failure scheme delay timer can be bypassed so that the BFP will operate with no intentional delay if a breaker failure initiate signal is received.
- Loss of mechanism energy storage during non-fault conditions can prevent satisfactory interruption of current in breakers that require stored energy for the opening stroke, if called upon, potentially leading to a true breaker failure. Loss of mechanism energy storage can be detected with pneumatic or hydraulic gauges, micro-switches, or undervoltage relays. For a loss of stored energy below the rated minimum value, breaker manufacturers typically recommend blocking the tripping and closing of the circuit breaker to prevent mechanical or electrical failure. In this case, the breaker failure delay timer can be bypassed so that it will operate with no intentional delay. The breaker manufacturer might be consulted to verify the loss of energy storage is not a transient condition that could occur during the normal operation of the circuit breaker.
- Contact flashover in an open breaker can lead to catastrophic failure. This could be caused by a re-strike of an opening breaker or a surge through an already open breaker that produces dielectric breakdown across the contacts.
- Failure of a circuit breaker to close when called upon is not traditionally defined as a breaker failure condition, since it is not associated with a protective relay trip. This can, however, have significant impact on the power system and may need to be considered in the operating scheme. Many reclosing schemes include failure to close logic.

- Failure of a circuit breaker to close in the expected time while attempting to connect a generator to the system can cause severe damage to the generator and turbine if the breaker eventually closes when the generator is out of phase with the system. This can occur for a number of reasons, but especially if the breaker has sat for an extended time in very low ambient temperatures. It is recommended to isolate the breaker and operate it a few times before the synchronization is actually attempted. Protection schemes are also available to monitor the closing time of the breaker and trigger the breaker failure-to-close scheme if the close has not occurred within an appropriate time following synchronism.
- Non-fault related failures are also possible. An example would be failure to interrupt load current, or mechanical failure during switching operations. These failures can be addressed within more complex BFP schemes.

Numeric relays have some ability to identify impending failure of a circuit breaker. This can be accomplished by identifying degraded performance, such as changes in operate or clearing times. These schemes can also track predictive quantities such as accumulated interrupted current or number of operations.

Breakers with single-phase tripping present additional constraints for BFP.

6. Breaker failure protection schemes

This clause describes breaker failure schemes that have received acceptance by the industry and are used in utility power systems. Common elements of a breaker failure to interrupt scheme include the following:

- Scheme initiation by a breaker trip signal such as a protective relay that has operated to trip the breaker
- Determination that the breaker has tripped successfully by monitoring reset of an overcurrent element (50BF) that responds to each measured phase current (50P) and possibly the sum of these phase currents (50G), monitoring change in state of the circuit breaker auxiliary contact (52a, 52b, or 52aa), or some combination of these methods
- A timer
- Some means to trip and block closing of adjacent breakers
- Optional: A separate output contact to issue a re-trip signal to the circuit breaker before issuing a breaker failure output with sufficient margin such that successful opening of the circuit breaker will prevent an undesired breaker failure output
- Optional: A teleprotection channel to key a DTT and to cancel reclosing of remote circuit breakers

Schemes are illustrated using logic diagrams. Many of the schemes could also be illustrated by using conventional dc control schematics.

When choosing a scheme it is important that the interactive behavior of the aggregate components is well understood. Schemes vary in their degree of dependability versus security. Behavior peculiar to a particular type of relay can affect each scheme differently. Behavior can be impacted by equipment replacements and firmware upgrades.

Factors to be aware of might include the following:

- Method of seal-in or latching of the primary relay output after fault detection
- Presence or absence of local current/fault detector supervision of the primary relay
- Sensitivity (pickup and dropout) of the 50BF current detectors
- Interaction of the scheme with local and remote automatic reclosing
- Impacts of credible component failures such as welding shut of relay output contacts
- Reset of the BFP scheme

6.1 Basic breaker failure scheme

Basic BFP provides a means to trip adjacent current sources if a fault is detected by protective relays and the associated breaker(s) fails to interrupt the fault. Figure 2 is a logic diagram showing a basic breaker failure scheme. Figure 3 shows a typical timing chart for this scheme.

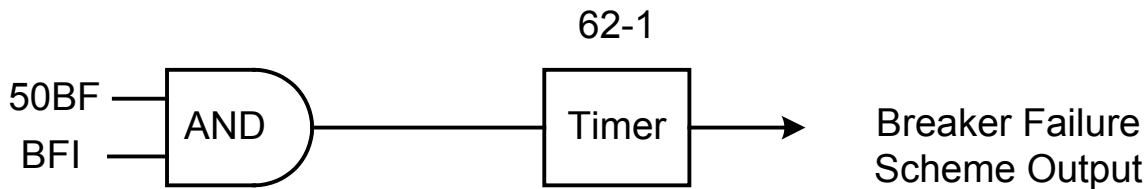


Figure 2—Basic breaker failure scheme

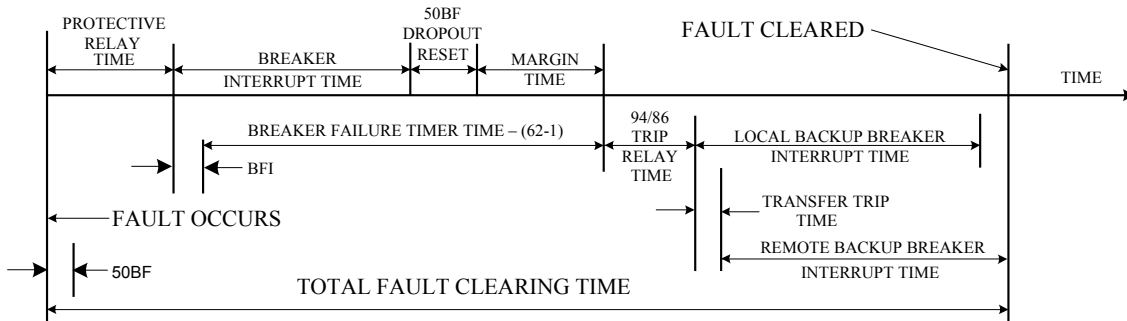


Figure 3—Fault clearing timing chart

The following two conditions are used to monitor proper breaker operation during a fault clearing operation:

- a) The presence of current flow in the breaker (50BF) and
- b) A protective relay trip signal (BFI).

The breaker has failed to operate properly if both of these signals are present for a period greater than the expected breaker clearing time. A delay on pickup timer (62-1) is set to a time delay that exceeds the breaker normal clearing time with margin. If current is still flowing through the breaker when the timer times out it is determined that the breaker has failed. If the breaker operates properly, either one or both of the 50BF or BFI inputs will de-assert and stop the operation of the timer.

When a breaker failure scheme operates [breaker failure timer (62-1) times out], a number of actions are initiated by the scheme. Depending on design philosophy, the number of contacts required, the interrupting rating of the output contacts, or relay targeting requirements, auxiliary devices (94) may be used. Often, a lockout relay (86BF) is used as an auxiliary device.

6.2 Basic breaker failure with re-trip logic

Re-trip is a separate output contact from the BFP intended to prevent undesired breaker failure operations and consequent loss of adjacent circuit elements for certain causes such as human error during relay testing, false initiation of BFP from dc transients induced on control circuit wires, and failure to trip due to loose or shorted breaker trip circuit wiring or non-functioning trip coils. Re-trip logic is designed to issue the re-trip signal to the breaker with sufficient margin such that the successful opening of the breaker due to the re-trip signal will cause the 50BF element to drop out (and the 52a to toggle open) before the breaker failure timer expires.

The re-trip circuit helps to alleviate a consequence from an easily made but infrequent operating error. The error occurs while performing relay testing on one of the two sets of line relays while the line is still in-service. The trip circuit for the relay under test is disabled but the breaker failure initiate circuit is not. When the test produces a trip output from the relay, the breaker failure initiate circuit could cause a breaker failure relay (BFR) operation if the load current is above the breaker failure current detector. With a re-trip circuit, the line breaker will be tripped, but the more serious result of the breaker failure operation is avoided.

Power circuit breakers with two (or more) trip coils yield the opportunity to provide redundant breaker actuation using separate, independent trip circuits. Best practices for initiating BFP where two breaker trip coils are provided are described by 7.6 and illustrated by Figure 29.

Where primary relays are not redundant, or where it might be difficult to separate tripping outputs such as for legacy electromechanical phase and neutral overcurrent relays, the breaker failure re-trip contact might be applied to the second trip coil circuit to mitigate for failures of the first trip coil circuit (with the non-redundant or legacy relays).

Some utilities choose to apply both redundant relays of a protected circuit to a single trip coil and rely on a separately fused breaker failure re-trip contact to operate the second trip coil to mitigate for failures of the first trip coil circuit.

Some utilities add a time delay (62-2 of Figure 4) to the re-trip circuit to help identify, by slower measured overall trip time of the breaker due to the delayed re-trip output, when a failure to trip by the first trip coil circuit occurs. When the breaker failure scheme has internal sequence of events recording, the information can be used to determine whether the breaker operation occurred by the re-trip circuit or by tripping on the initial fault detection, and this might be used to inform maintenance personnel that a breaker inspection may be beneficial if the breaker successfully opens. For this scheme, the re-trip time-delay-on-pickup setting (62-2) needs to be coordinated with the breaker failure timer (62-1) to be effective. The operating speed of the output contacts used for re-trip is accounted for in the overall time-delay settings since slower speed output contacts may be used for re-trip activation. For inherently slow clearing breakers, the coordination between the re-trip and breaker failure timers is a consideration. Additional system stability and protection coordination studies may be required whenever coordination of the re-trip and breaker failure timers requires the breaker failure timer to be extended.

Figure 4 illustrates the addition of re-trip logic. Most utilities set the 62-2 timer to zero time. The dotted line illustrates an alternative connection of the re-trip timer to the output of the AND gate, which some manufacturers might implement for additional security.

Re-trip logic may not be desirable in some cases for security reasons. For example, the re-trip logic may be viewed as more of a risk for a false trip than an improvement to reliability in applications with redundant protection schemes. Avoid re-trip logic that may unnecessarily react to transients or temporary dc grounds. The contact change-of-state recognition time needs to be greater than the length of any expected dc transient. A one-quarter cycle delay is typically sufficient. The pickup level of an input circuit needs to be high enough to be secure for a battery ground situation. An input pickup level greater than one half the battery voltage is typically sufficient.

The re-trip signal may be for three-phase tripping only or for individual breaker poles for selective single-phase tripping. If integrated within the same hardware device as the initiating protection function, this trip signal may be issued via separate output contacts from those with which the device issued the initial trip output.

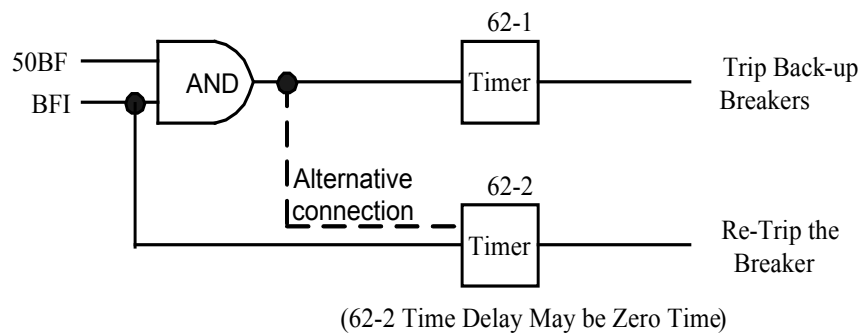


Figure 4—Breaker failure re-trip

6.3 Breaker failure scheme for dual breaker arrangements

The logic shown in Figure 2 has a disadvantage in multi-breaker line protection schemes, such as ring bus and breaker-and-a-half schemes, where current in one breaker may be insufficient to pick up the current/fault detector until the other breaker trips. The logic shown in Figure 5 permits the breaker failure timer (62-1) to start timing with only the BFI input, eliminating the delay that might occur if the current detector input (50BF) were also required to start the breaker failure timer, as in Figure 2. The fault clearing timing chart for this scheme is the same as shown in Figure 3, except the 50BF pickup may occur later.

The breaker failure scheme shown in Figure 5 allows the breaker failure timer to start on initiate without the supervising 50BF element asserted. Caution is advised when applying this scheme with protection schemes that can assert a trip when the breaker is open. One example is line current differential (87L) protection. In a reclosing sequence, the remote terminal can time out its open interval first and close into a permanent fault. The 87L relay at the local terminal will assert based on the remote terminal current and start the timer. Then, when the local breaker's open interval times out and closes into the fault, the breaker failure timer is already partially timed out, which may not allow sufficient time for the breaker to successfully clear the fault. This can result in an inadvertent breaker failure backup trip. Other similar schemes are shown in Figure 6, Figure 8, and Figure 25.