WECC

Application Guide for Echo Keying Logic on Permissive Overreaching Transfer Trip Schemes

Relay Work Group

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Table of Contents

Introduction

The purpose of this guide is to provide power system relay engineers with basic criteria to allow secure and dependable application of echo keying on permissive overreaching transfer trip (POTT) protection schemes. It is not a detailed design specification. The need for this guide was determined following the analysis of multiple system disturbances where one factor contributing to the disturbance was the application of an echo keying scheme without sufficient security.

General Comments

Security and Dependability

Security is a measure of the certainty that power system relays will not operate for faults or conditions outside the intended zone of protection. POTT schemes need to be secure when subjected to emergency loading, external faults or power swings, and care needs to be exercised when setting and applying POTT schemes to prevent unintended operation. [1].

Dependability is a measure of certainty to operate when required. The POTT scheme provides a level of performance to the Protection System that can provide high speed clearing over 100% of the line. If this is a requirement to meet reliability standards then a certain amount of redundancy must be built into the Protection System to insure the proper level of performance is achieved.

The owner must determine the level of security and dependability to employ and this may determine which available features of the POTT scheme to use.

WECC/NERC Criteria

In addition to the recommendations in this guide, the protection system designs must meet all applicable WECC Minimum Operating Reliability Criteria [2] and NERC Reliability Standards, including the NERC Relay Loadability Standards [3,6]. This applies to all elements of the Bulk Electric System (BES) under WECC jurisdiction.

POTT Protection

Pilot protection schemes, like POTT, are applied when faster clearing times are needed to maintain the performance of the BES. The POTT scheme logic requires an overreaching element at each terminal to detect forward faults, relative to the installed relay location. Each relay sends permission to the remote terminal over the communications system, indicating that the fault is on the protected transmission line and allowing each terminal to trip. Without a pilot protection scheme (including line differentials), the isolation of faults at the ends of the line require a time-delayed relay operation.

A POTT scheme is intended to provide high speed isolation for all faults on 100% of the protected transmission line. It is very dependent on the permissive signal and will not operate if the signal is lost. Dependability of the POTT Scheme is limited when the permissive signal drops out due to communications channel noise. The relay engineer needs to consider the application of the communication channel and determine how to protect the line during a loss of the channel and the permissive signals.

There are several conditions that require a modification in the POTT scheme to improve dependability. When the local terminal is open, faults will not be detected by the open terminal and no permission will be sent. To get high-speed clearing for this condition, the POTT scheme can use an "echo keying" feature. For example, with the local terminal open, it is common to "echo key" the received permissive signal. If a fault occurs on the line, the permissive signal from the closed end of the line is "echoed" back by the relays at the open end of the line. This allows high-speed protection for the entire line.

The echo keying can also be made more dependable when the line terminal is open by considering either of the following options/modifications:

1. Enable the echo key when the local terminal is open.
2. Send permission continually if the local terminal is open (such as open end permissive keying).

The keying permissive elements of POTT schemes are often supervised by reverse directional relaying elements that prevent permissive keying from occurring when a reverse element operates. The reverse directional element increases security for external faults. If a reverse fault is detected by the relay, this logic can also prevent the echo of the permissive signal.

The relay engineer will set the reverse-reaching directional elements. Since these settings are not automatic, the relay engineer must ensure that these elements are not only asserted for reverse faults, but also for power swings in the reverse line or lines, and any other abnormal power flow conditions. These abnormal conditions may not be well defined and can lead to misoperations.

Echo Key Application

The relay engineer should work in conjunction with the appropriate personnel (planning, operations and maintenance) to determine the clearing requirements for the transmission line(s). If the planning, operations and maintenance personnel determine that clearing times with the remote terminal open must occur faster than a time delayed operation to maintain reliable operation of the BES, a method such as echo keying can be employed.

When echo keying is applied, the engineer should focus on methods to increase security, including the following:

- Reverse directional elements that do not detect power swings will allow echo keying.

- Reverse directional elements that do not detect emergency power transfer conditions (high current at a mostly resistive angle) will allow echo keying.

Weak Terminal Echo Key Application

Weak source, or weak infeed, conditions at one terminal may not allow the POTT scheme to make a reliable determination of a fault location. This may prevent the relays at the weak source terminal from sensing some faults in the forward direction. If the forward fault decision is not reliable, weak source logic with echo keying may be used. The weak source logic will convert the received permissive signal to a local trip and echo key to the initiating terminal.

In order for the weak terminal to convert the received permissive signal to a local trip, the following supervisory conditions should be met [4]:

1. No reverse elements are asserted.
2. One or more phase-to-phase undervoltage elements are asserted or a residual overvoltage element is asserted.
3. The local terminal breaker(s) is(are) closed.
4. The remote terminal permissive signal is received for a specified time.

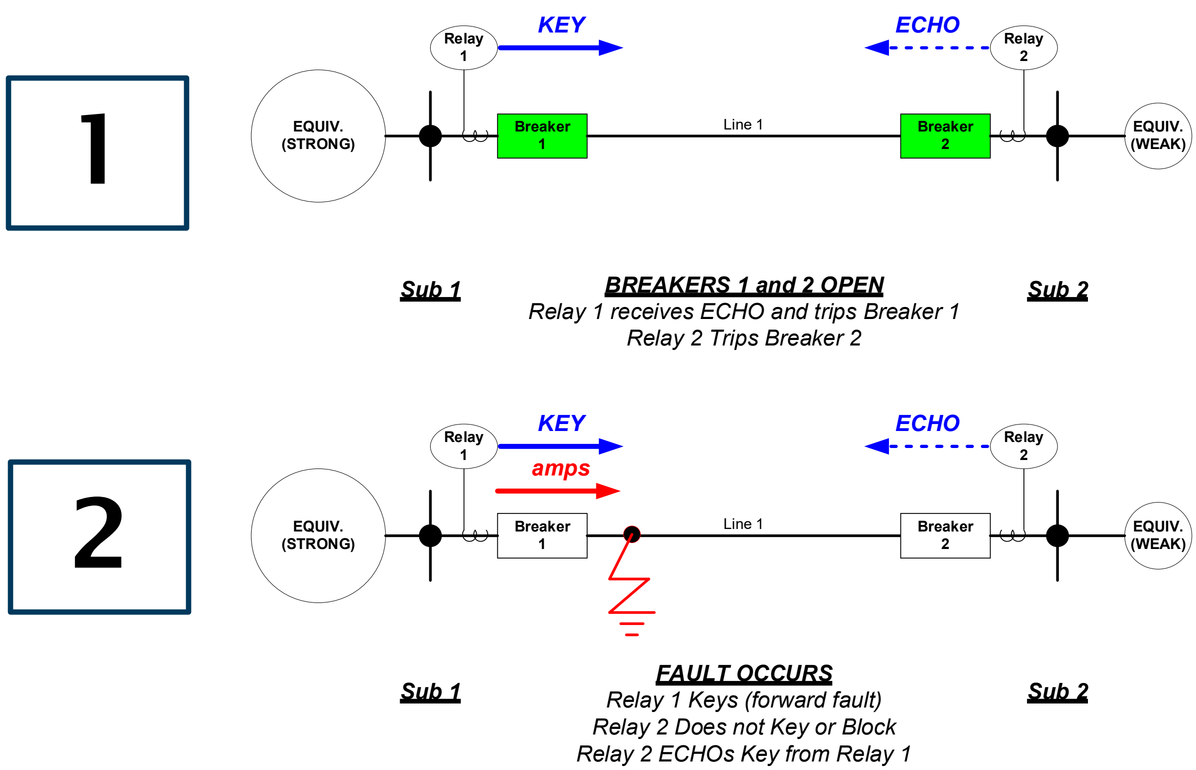


Figure 1—Weak Terminal Echo Tripping

A possible exception to Item 2 (above) exists if the protected line includes line sectionalizing switches, the statuses of which are not monitored by the scheme. An open switch may prevent voltage elements from sensing a fault condition on the far side of the open switch. For this condition, it is usually appropriate to echo key the permissive signal, but without initiating a local trip.

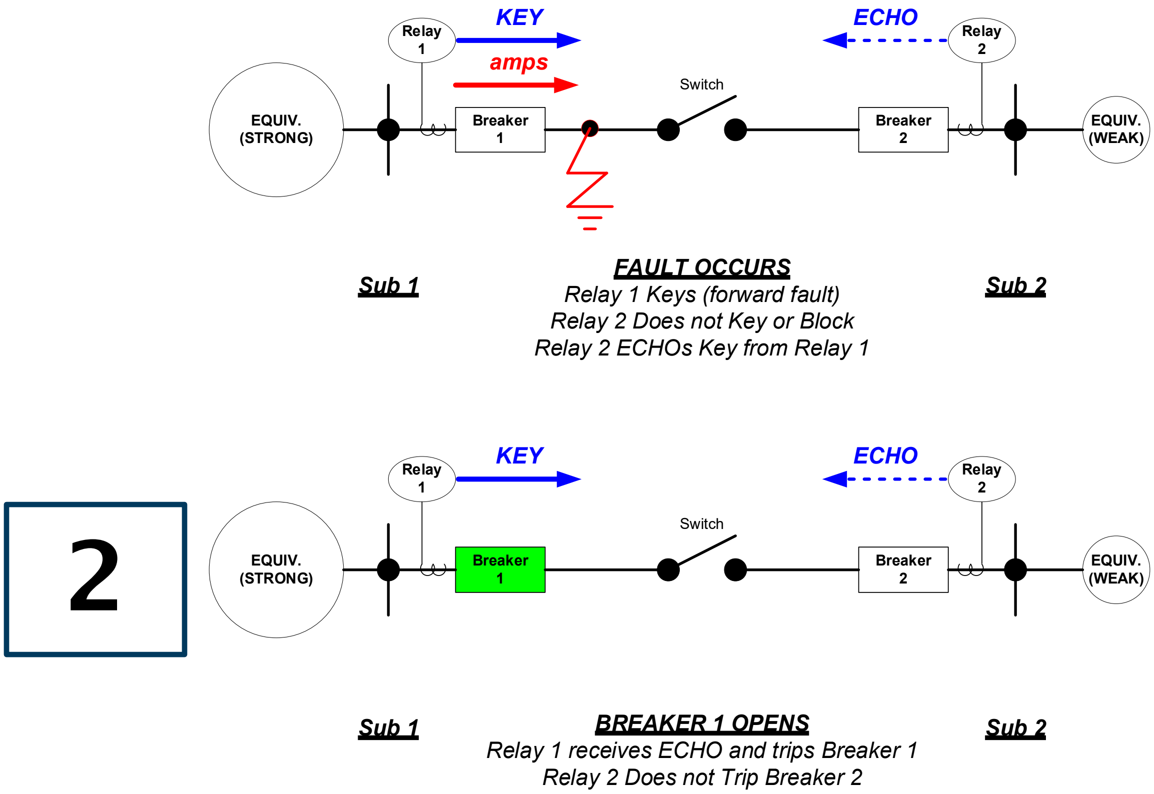


Figure 2—ECHO Keying with Line Switches

Another approach allows echo keying from the weak source with sequential clearing at the remote terminal. In some electrical configurations opening of the remote strong terminal will cause the local relays at the weak terminal to sense the forward fault and initiate a trip. The relays and breakers at the two terminals operate in sequence.

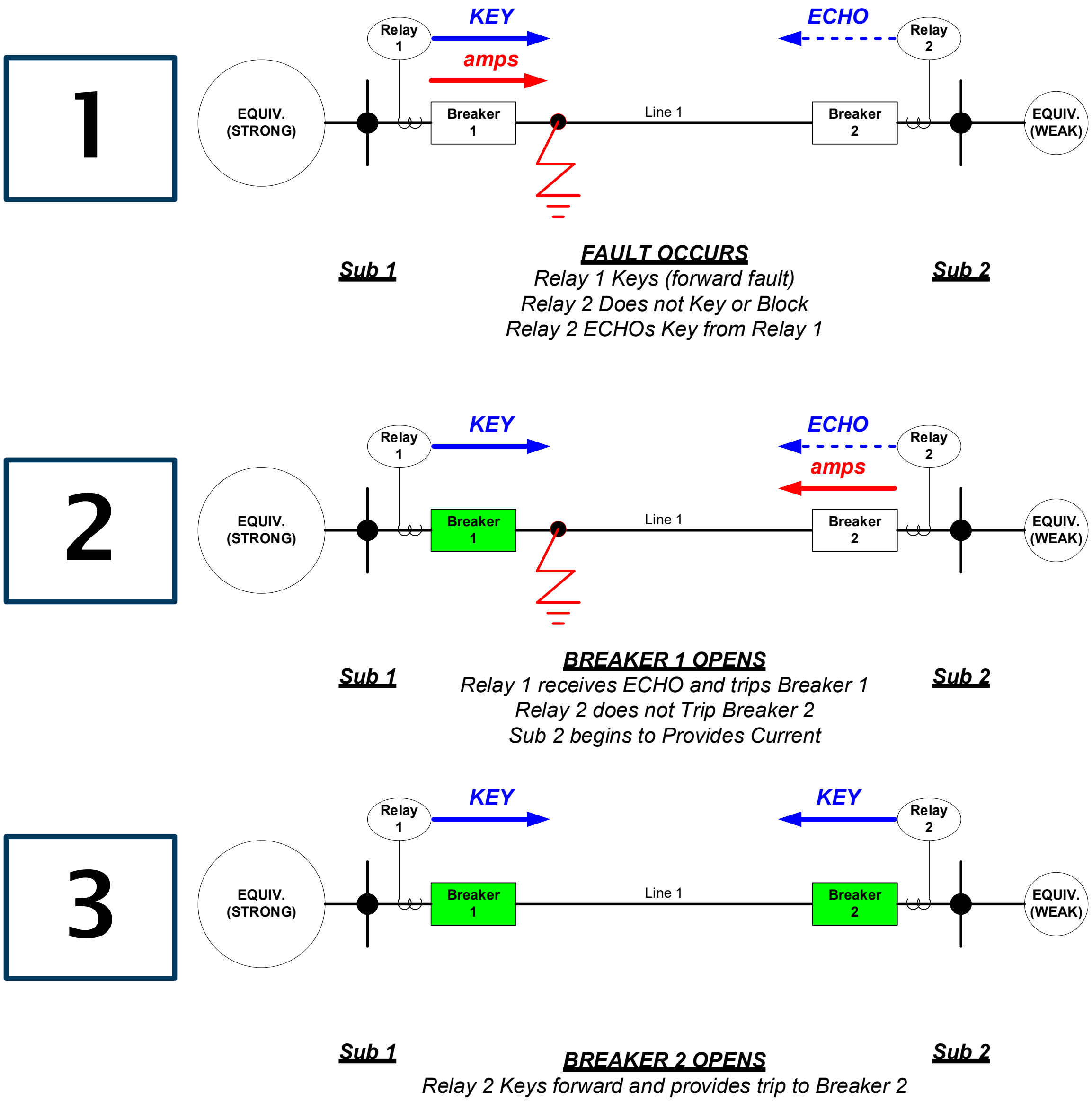


Figure 3—Sequential Tripping of Remote Terminal

Settings Coordination

All overreaching overcurrent and impedance elements that initiate permission to trip must be coordinated with the remote-end reverse-reaching elements to ensure that they do not overreach the reverse elements.

It is important to enable and use the same types of relay elements in the reverse directional relay for blocking as are used in the forward directional relay for keying permission. For example, if ground overcurrent forward directional elements key permission, there must be reverse directional ground overcurrent elements at the remote terminal. The sensitivity of these relays must be such that the blocking relay is as sensitive to reverse faults as the forward keying relay is to these same faults.

Impedance based relays and relay elements must be coordinated in the same manner. It is also important for the relay engineer to understand the significance and coordination of any load encroachment logic and settings used on the blocking or reverse directional elements. The sensitivities of the load encroachment at all terminals (reverse and forward) should be considered.

Use of impedance mho elements will result in an area of possible miscoordination (see Figure 4 below). The area of miscoordination must be reviewed to determine whether it presents an unacceptable system risk. Failure to do so may result in an incorrect echo and an unnecessary operation.

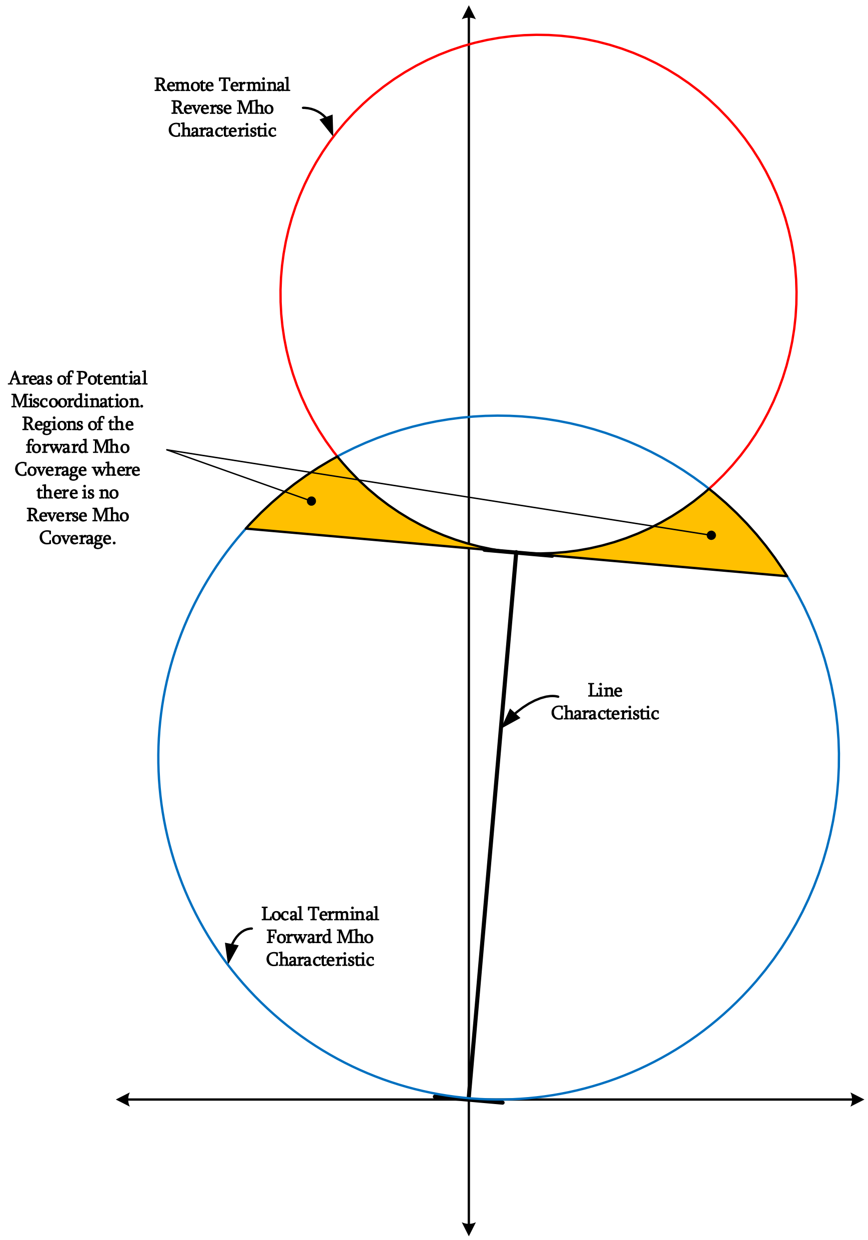


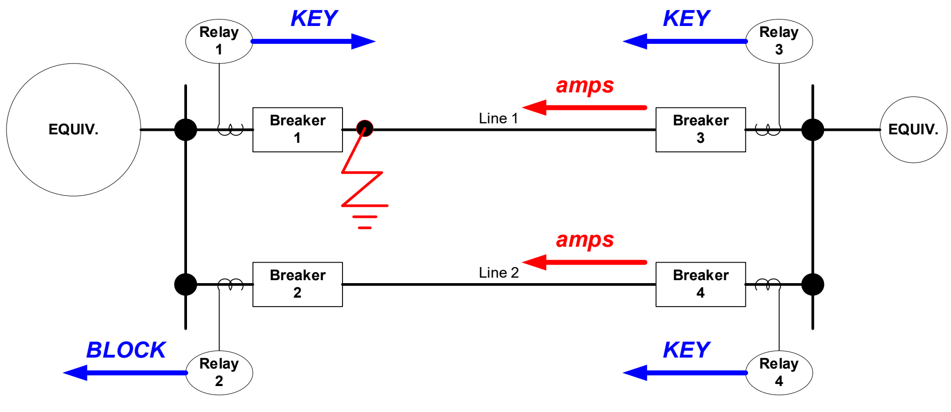
Figure 4—Gaps in Local and Remote Terminal Mho Coordination

POTT on Parallel Lines

Parallel lines will require careful consideration to coordinate elements of the POTT scheme for faults on one of the lines. This discussion also applies to line terminals that are part of any parallel paths, in addition to lines connecting the same two buses. It is possible for the two terminals of the faulted line to open at different times. When this happens the current on the non-faulted line will suddenly reverse. If the keying and blocking elements and timers are not coordinated properly a misoperation will occur. The Echo feature or weak terminal logic can also complicate this process, but proper settings will improve security.

The reset of the blocking elements at breaker 2 must be delayed to allow the keying elements at breaker 4 to drop out. This time is usually equal or greater than the propagation delay of the communication channel.

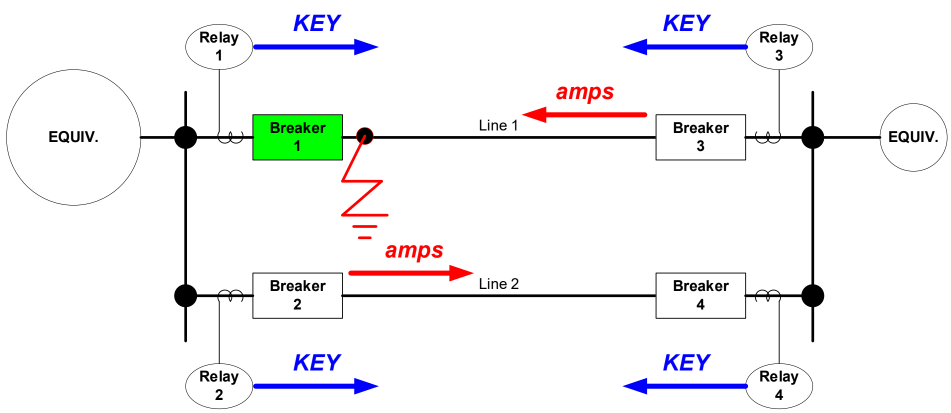
1



Sub 1 ***Sub 2***

FAULT OCCURS
Relay 1 Keys (forward fault)
Relay 2 Blocks (reverse fault)
Relay 3 Keys (forward fault)
Relay 4 Keys (forward fault)

2



Sub 1 ***Sub 2***

Breaker 1 Opens
Current on Line 2 Reverses
Relay 1 Keys (forward fault)
Relay 2 Block Resets (forward fault)
Relay 2 Keys (forward fault)
Relay 3 Keys (forward fault)
Relay 4 Keys (forward fault)

3

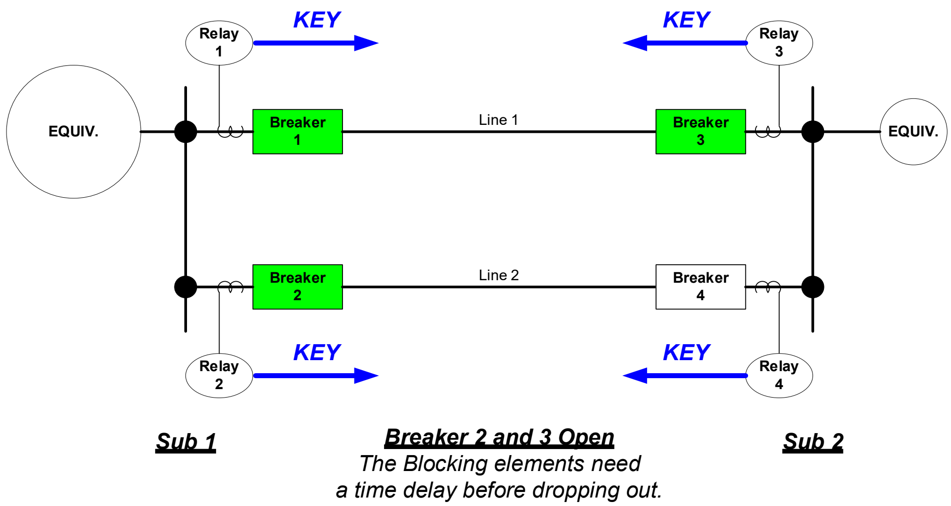


Figure 5—ECHO Logic and Parallel Lines

Relay Qualification Testing

It is recommended that any new relay to be applied on the BES should be tested and installed using the Guideline [5]. In addition, any new relay or relaying system should be tested and its performance accepted for extreme loading conditions and swing conditions. Acceptable loadability compliance methods are set forth in [3] and [6].

Disclaimer

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Additional Resource Information

- [1] Western Electricity Coordinating Council, Relay Work Group, *WECC Disturbances Illuminate Protection Tribulations*, Western Protective Relay Conference, Washington State University, Spokane, Washington, October 2005.
- [2] Western Electricity Coordinating Council, *Minimum Operating Reliability Criteria*, April 6, 2005.
- [3] North American Electric Reliability Corporation, Standard PRC-023, *Transmission Relay Loadability*.
- [4] P.M. Anderson, *Power System Protection*, 1st edition, IEEE Press Power Engineering Series, 1998.
- [5] Western Electricity Coordinating Council, Relay Work Group, *Installation and Maintenance Guideline for Protective Relay Systems*, May 7, 2001.
- [6] North American Electric Reliability Corporation, PRC-023 Reference, *Determination and Application of Practical Relaying Loadability Ratings*.

Version History

Modified Date	Modified By	Description
July 10, 2008	Relay Work Group	Drafted and approved document
March 15, 2021	Relay Work Group	Updated formatting and ensured relevance