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Use of Circuit Breaker Position Indication in Breaker Failure Protection

System Protection and Control Subcommittee

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RELIABILITY | ACCOUNTABILITY

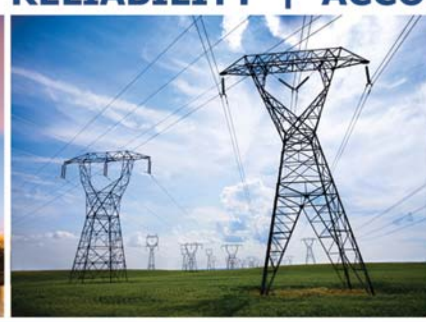

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Table of Contents

This technical document was approved by the NERC Planning Committee on December 14, 2011.

Introduction

A NERC event investigation identified concerns regarding use of circuit breaker position indication in breaker failure protection schemes. In this event the breaker failure protection did not operate when one pole of the circuit breaker failed to open due to a mechanical problem. The breaker failure protection scheme utilized circuit breaker position indication in series with the fault current detector. The logical "AND" created with this series arrangement prevented operation because although fault current was flowing, the circuit breaker mechanical problem resulted in a disagreement between the circuit breaker 52a contact and the circuit breaker main contacts.

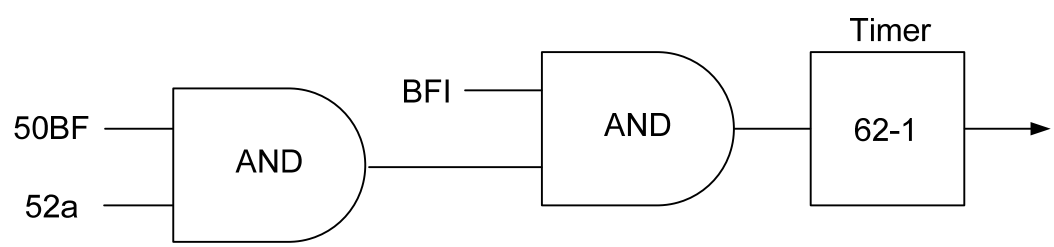
The investigation resulted in publication of a Lesson Learned and a recommendation that the NERC System Protection and Control Subcommittee (SPCS) assess whether industry guidance on this subject is sufficient and if appropriate, pursue modifications to IEEE Guide C37.119 with the IEEE Power System Relaying Committee.

Event Description

During the event, a breaker failure protection scheme did not operate when one pole of the circuit breaker failed to open due to a mechanical problem, resulting in backup protection system operation on several lines to clear the fault. Prior to the fault, an operating rod became disconnected from the gearing mechanism on the B-phase of a circuit breaker. Upon detecting the fault, the protection system operated properly and initiated both a circuit breaker trip and the breaker failure protection scheme. The circuit breaker A-phase and C-phase main contacts opened as expected when the circuit breaker was tripped, however the B-phase main contacts failed to open as a result of the disconnected operating rod. The circuit breaker 52a auxiliary contacts were unaffected by the disconnected operating rod and opened as a result of the trip. This resulted in an incorrect circuit breaker position indication being provided to the breaker failure control logic.

Based on the breaker failure logic design, two conditions were required for the breaker failure protection scheme to operate: 1) operation of the 50 BF fault current detector, indicating the presence of fault current; and 2) the circuit breaker 52a auxiliary contacts remain in the closed position, indicating the circuit breaker had not opened. Figure 1 illustrates one example of a breaker failure logic design using a logical AND to operate only when fault current is present and the circuit breaker position indication is closed. In this example the fault current and breaker position are combined in a logical AND with the breaker failure initiate (BFI) signal from the protective relays for the faulted zone.

Figure 1: Example of Breaker Failure Logic Requiring Fault Detector Operation AND Circuit Breaker Position Closed Indication



Although the B-phase 50BF fault current detector was picked up due to the fault current, the 52a contacts incorrectly indicated an open circuit breaker. Since only one of the two required conditions was true, the breaker failure scheme did not operate. The consequence was the operation of back-up relaying on multiple lines to clear the fault, resulting in a more severe outage than if the breaker failure protection had operated.

Industry Guidance

Breaker Failure Modes

Section 6 of C37.119 discusses breaker failure modes. The two primary failure modes involve failure to trip and failure to clear.

A failure to trip is characterized by the breaker contacts failing to open after the trip circuit is energized by the protection system. This could be caused by an open or short in the trip circuit or the breaker trip coil. It also could be the result of a mechanical problem such as occurred in the event described above, which may result in the 52a and 52b contacts changing state even though the circuit breaker main contacts have not opened, resulting in an incorrect indication of the circuit breaker main contact position.

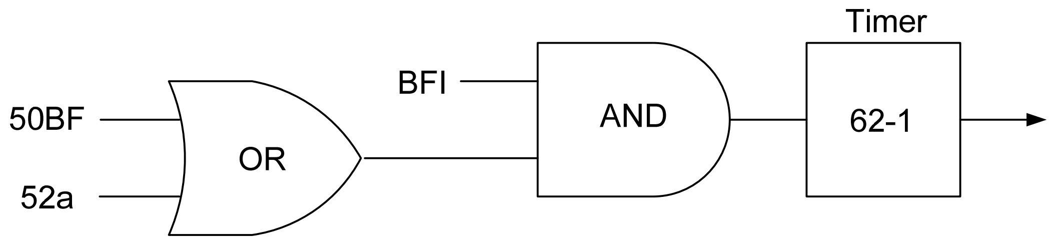
A failure to clear is characterized by the breaker failing to extinguish current even though the breaker contacts have opened. A failure to clear may result from incomplete contact parting caused by a mechanical problem, loss of dielectric strength, restrike of an opening breaker, or a surge that results in a flashover of an open breaker. In each of these cases the 52a and 52b contacts will change state even though fault current will continue to flow.

Breaker Failure Protection Schemes

Section 7 of C37.119 discusses breaker failure schemes that have received acceptance by the industry and are used in utility power systems. Several different logic designs are presented. The guide discusses the use of breaker position indication for breaker failure protection in three schemes; however, there are no schemes in which the breaker position indication is placed in series with the fault detector function to produce a logical AND requirement.

The three schemes utilizing breaker position indication are discussed in sections 7.6, *Minimal current scheme*; 7.7, *Fast 52aa, dual timer breaker failure scheme*; and 7.8, *Triple timer breaker failure scheme*. Breaker position indication is useful when it is possible that minimal fault levels will occur that are insufficient to operate the fault current detectors. Some examples of when this may occur are turn-to-turn faults in a generator or transformer, transformer or generator faults limited by impedance, low side faults on transformers with high transformation ratios (e.g., station auxiliary transformers), and ground faults on delta transformer windings. In each case, the logical combination of breaker position and current detection always produces a logical “OR” requirement to assure the scheme will operate properly for low-magnitude faults. The guide specifically states, “While operation of the auxiliary switch might properly indicate that the breaker mechanism has operated, it is not sufficient indication that the circuit breaker has interrupted the fault current.” Figure 2 illustrates one example of a breaker failure logic design using a logical OR requirement to provide operation for failures involving minimal fault current.

Figure 2: Example of Breaker Failure Logic Requiring Fault Detector Operation OR Circuit Breaker Position Closed Indication



SPCS Assessment

The NERC Lesson Learned discusses the importance of weighing the advantages and disadvantages of combining breaker position indication and fault current indication to create a logical AND requirement versus a logical OR requirement to supervise breaker failure protection. Breaker failure protection is initiated when protection systems command a circuit breaker to clear an identified fault. Failures of breakers to clear faults occur infrequently; however, the risk to equipment and overall system reliability of failing to clear a fault when such breaker failures occur demands that breaker failure protection schemes are designed with a high level of dependability. To assure dependability, correct operation of breaker failure protection schemes is necessary when fault current is detected through the circuit breaker for longer than the breaker failure timer setting, regardless of the breaker position indication. Dependability may be enhanced further for certain applications by combining breaker position indication with fault current detection to create a logical OR requirement. Such enhancements are appropriate when the potential exists for low-grade faults that may not be detected dependably by the fault current detector.

Creating a logical AND compromises the dependability of the breaker failure scheme not only for failures to trip such as occurred for the event described in the Lesson Learned; it prevents operation of the breaker failure protection scheme for failures to clear resulting from incomplete contact parting, loss of dielectric strength, breaker restrike during opening, or flashovers of the main contacts. Security of the breaker failure protection scheme can be improved by creating a logical AND requirement with breaker position indication and fault current detection. However, the negative impact on dependability outweighs any improvement in security unless consideration is given to address the failure modes described above.

Conclusions

Breaker failure protection design should consider all potential failure modes and balance dependability and security of operation. Creating a logical AND by placing the breaker position indication and fault current detection in series can improve security; however, it will not provide dependable operation when the breaker position indication is not in agreement with the main contact position due to mechanical failures within the breaker, and for failures to clear resulting from incomplete contact parting, loss of dielectric strength, breaker restrike during opening, or flashovers of the main contacts. The potential consequences of failing to clear a fault must be considered when evaluating the balance between dependability and security in a breaker failure scheme.

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