

Operations Intelligence Provided By Circuit Breaker Condition Monitors

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Abstract -- From a number of perspectives, the active devices in an electric power delivery system, the switches, can be characterized as the weakest links in the network, as opposed to the passive components, lines and transformers. Yet the unerring action of switching devices is critical to power delivery quality and reliability.

On-line power circuit breaker monitors are widely used today by maintenance groups for real-time reporting of breaker operating conditions. These monitors provide an effective means to predict and prevent breaker misoperations and failures. With the availability of real-time data, scheduled maintenance procedures are giving way to cost-effective reactive maintenance plans to reduce maintenance costs and out-of-service time. This paper presents the basic functions and benefits of the on-line circuit breaker condition and wear monitor in condition-based and reliability-centered maintenance programs.

The value of historic operating data goes beyond the immediate and obvious need to assess breaker reliability. Time-stamped breaker operating data provide valuable operations intelligence to enhance delivery reliability and improve power quality. Two applications of circuit breaker monitor data utilized as operations intelligence are given. A contingency breaker coordination scheme initiated by a condition alarm on a downstream breaker is described. The means to phase-target maintenance to remedy breaker nuisance tripping is also presented.

Key Words

Circuit breaker monitoring, breaker failure, on-line, relays, system protection, SCADA, JIT, RCM.

I. INTRODUCTION

The advent of microprocessor based, on-line breaker condition monitors has allowed Operations and Maintenance Engineers to apply reliability centered (RCM), predictive (PdM), and just-in-time (JIT) maintenance techniques to circuit breakers. These breaker condition monitors examine select breaker operating characteristics, which are used to alarm for JIT maintenance and provide trending data input to RCM and predictive maintenance programs.

Symptoms of wear, possible failure, and failure that can be detected by on-line monitoring can be placed into four general categories (1):

Contact Wear - Damage from excessive interrupting duty, which is cumulative. Catastrophic failures have occurred under this circumstance.

Dielectric Compromise - Contaminated oil, worn baffles, nozzle ablation, and other items that cause excessive arc duration. These situations cause a longer clearing time, which may gradually increase to infringement on the breaker failure time.

Mechanism Problems - Mechanical issues such as worn parts, "frozen" linkages, faulty latches, and pneumatic or hydraulic system malfunctions. These problems may either gradually develop (degradation), or suddenly develop from a component failure.

Control Circuit Failure - Shorted coils, open coils, open or shorted circuits. These problems may either develop suddenly, as in a short circuit from wire abrasion or open circuit from termination failure, or gradually, as in insulation breakdown in a coil leading to a short.

Breakers are monitored on-line to collect data from each and every operation, as well as to provide the status of control circuits. On-line monitors detect anomalies as they occur, and report these incidences to Operations through SCADA. Monitors provide operations intelligence quickly, automatically, and decisively as input to protection and control remedial schemes.

The possibilities for remedial system protection schemes depend on the importance of the breaker, power apparatus configuration, and available protection and control infrastructure.

Logged breaker event data, stored on-board the monitor or uploaded to local or central operations databases, provides information on breaker and line conditions. This intelligence is used to specify, prioritize, and schedule maintenance to remedy power quality problems originating in the distribution system.

II. BREAKER FAILURE - DEFINITION AND SYMPTOMS

A breaker failure occurs when a trip request is made to a breaker and the breaker does not trip within a required time interval. A breaker failure is a serious event, and appropriate contingency protective schemes must be developed to deal with it. These contingency schemes may involve the use of local or remote backup.

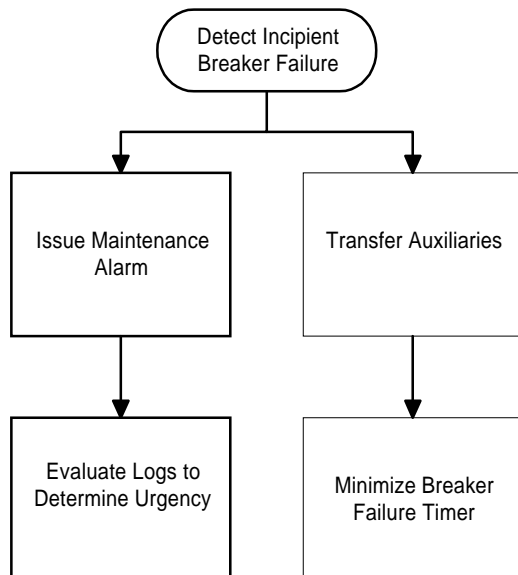


Fig. 1 Action Flow Chart - Minimize Generator Breaker Failure Timer

Local backup for a failed breaker involves using other breakers in the same substation to isolate and clear the fault that the failed breaker cannot clear.

Remote backup involves using breakers outside the substation to isolate and clear the fault that the failed breaker cannot.

III. REMEDIAL PROTECTION & CONTROL APPLICATIONS

A remedial scheme can be as simple as an action triggered on any of the alarm setpoints asserting at the monitor (Fig.1). Alternatively, a remedial action scheme might include an examination of the history of operations, and looking for degradation trends. Logs of past tripping operations can be examined for deviation patterns for the alarming condition.

Sudden deviations from normal operating limits could be viewed as those requiring urgent action, where incipient breaker failure could be assumed on the next operation. Where a gradual deviation trend is observed, combined with an alarm setpoint level just slightly exceeded, remedial action may be deferred, where a higher confidence of normal breaker operation might be assumed.

Sample remedial actions are described, each based on different requirements of trend information.

A. Minimize the Breaker Failure Timer

This remedial action considers minimizing the breaker failure timer for back-up tripping in the event of a trip request to a breaker where an incipient breaker failure is alarmed. This would be applicable, for example, to low (13.8kV) voltage (Fig.2). generator breakers feeding a GSU feeding high voltage breakers in a high voltage substation. Automatic reclosing would not be an issue here, so accelerating the breaker failure timer to the high voltage breakers might avoid stress on the system components and aid stability margin if the 13.8kV breaker were to fail. This would be accomplished on a local basis. To avoid an emergency motor bus transfer, an orderly transfer of auxiliaries could take place when the incipient breaker failure alarm was issued.

B. Breaker Isolation

Breaker isolation can be implemented by automatic control where an incipient breaker failure is alarmed (Figs. 3 and 4). This would be applicable in situations where other breakers can take the power flow, such as ring, breaker and one-half, and main & transfer bus arrangements.

As the probability of a bus fault is low, using this tactic can avert a bus-clearing breaker failure operation

with its attendant power delivery interruption. This would be accomplished on a local basis.

C. Trip and Reclose Blocking

To prevent breaker tripping and reclosing of a breaker when an incipient breaker failure is alarmed, a trip-and-reclose blocking scheme can be employed (Figs. 5 and 6). This action is applicable for radial distribution and sub-transmission feeders where the bus breaker could trip and reclose for a downstream feeder fault.

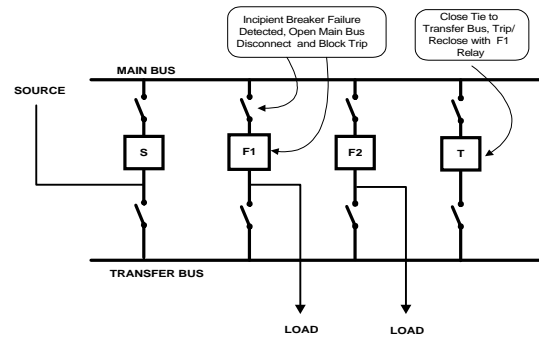


Fig.4 One Line Diagram, Main and Transfer Bus Breaker Isolation

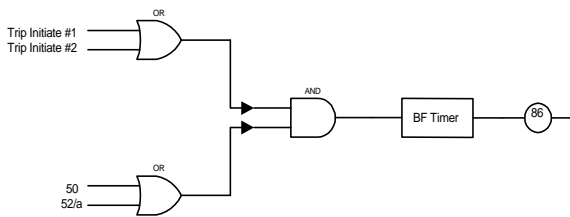


Fig. 2 Generator Breaker Failure Logic – BF Timer Minimized

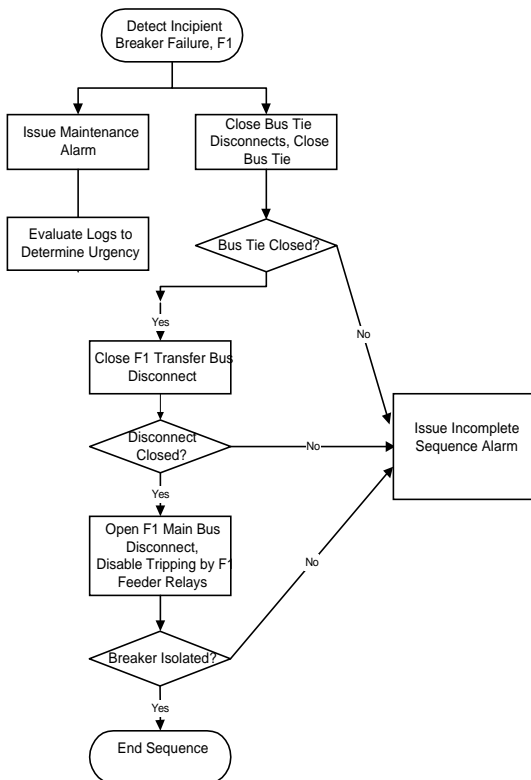


Fig. 3 Flowchart - Isolating a Breaker

The action can prevent a breaker failure and undesirable subsequent bus lockout. This strategy has

been applied by digital relays for “breaker saving” purposes when an instantaneous high set element is used to block a breaker whose fault interrupting duty would be exceeded by particular high fault levels (2). The same logic may be applied to incipient breaker failure blocking, avoiding a possible bus clearing and maximizing stability. This scheme would be accomplished on local basis.

If a high speed pilot was available, this strategy could be implemented remotely by transmitting the trip and reclose commands of the affected blocked feeder breaker’s relaying package to the remote upstream breaker for execution.

IV. POWER QUALITY IMPROVEMENTS

Electric utilities are becoming keenly aware that many sources of electrical noise exist within the distribution system. When the character of the noise is such that end-user applications are effected, customers perceive degradation in power quality.

A recent major customer satisfaction study indicates a small but statistically significant drop in customer perception of power quality across US utilities (3). The report warns investor-owned utilities that customer satisfaction is a key driver of equity value, and that utility managers had better mind the situation.

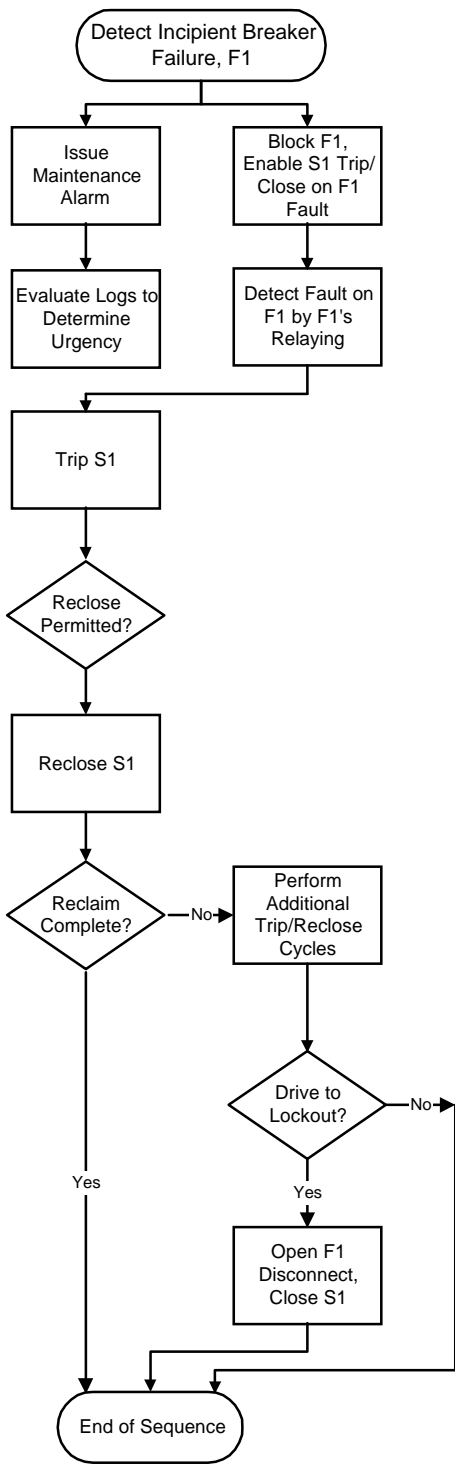


Fig. 5 Flow Chart – Trip and Reclose Blocking

The circuit breaker is one source of power quality degradation that is attracting attention. When a circuit breaker operates to open a portion of a distribution grid, transients are generated that can propagate many miles through to sensitive customer loads.

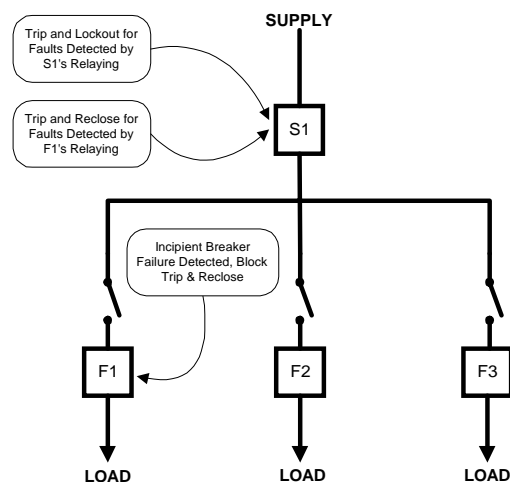


Fig. 6 One-line Diagram – Trip and Reclose Blocking

There isn't much that can be done, feasibly, to the thousands of existing circuit breakers to make them operate faster, or synchronously at zero crossings to minimize the generated transients. On-line breaker monitor logs and alarms provides unique operations intelligence that can be used by the utility to reduce the number of trip operations and thus improve the customer perception of power quality.

Individual breaker monitors, available for less than \$1000 and easily installed, have sufficient intelligence-gathering power to add significant benefit in a power quality improvement program. Monitors log all circuit breaker operations with date and time stamps. From logged fault current magnitudes, fault types can be identified.

Visual examination of circuit breaker history reports can clearly show repetitive faults known as "nuisance trips". Eliminating nuisance trips is one way utilities can improve power quality and reduce outage minutes.

One utility installed monitors on distribution feeder breakers in circuits displaying symptoms of poor power quality as reported by customers. After four months in the field, the monitors were interrogated with interesting results.

The fault data is presented in bar graph form in Table 1. Faults were occurring consistently on only one phase of the three-phase circuit. From this information, the utility quickly dispatched the tree-trimming crew to trim the roadside trees selectively,

eliminating the cause of the power quality complaints with minimum time and expense.

Fundamentally, power quality means power availability. An infrequent but high-impact power constraint is the breaker outage.

One large utility was particularly concerned with unplanned outages of power delivery equipment. One of their breaker monitors produced the data shown in Table I.

TABLE I
CIRCUIT BREAKER MONITOR LOG

#	I2TA	I2TB	I2TC	ACCA	ACCB	ACCC	DRWSE
9	9.9e+04	5.2e+07	5.2e+07	1.1e+08	1.4e+08	7.9e+07	AB ...
8	9.6e+04	9.6e+04	9.6e+04	1.1e+08	8.7e+06	2.7e+07	A
7	4.8e+07	4.8e+07	1.0e+05	1.1e+08	8.7e+07	2.7e+07	AB ...
6	6.1e+04	6.1e+04	6.1e+04	6.5e+07	3.9e+07	2.6e+07
5	3.9e+07	3.9e+07	1.0e+05	6.5e+07	3.9e+07	2.6e+07	. B ...
4	8.4e+04	8.3e+04	8.7e+04	2.6e+07	3.0e+05	2.6e+07	. . A..
3	2.6e+07	6.1e+04	2.6e+07	2.6e+07	2.2e+05	2.6e+07	. . A..
2	6.4e+04	6.4e+04	6.4e+04	1.6e+05	1.6e+05	1.6e+05	. . A..
1	9.6e+04	9.6e+04	9.6e+04	9.6e+04	9.6e+04	9.6e+04

The data represents a typical progression of the operating performance for a bulk-oil circuit breaker. Further review of the record showed that every fault that included phase B resulted in a restrike (shown as XX in the data table). Faults where phase B current was not excessive did not produce a restrike. This led the utility to suspect problems in the phase B interrupter. Maintenance crews were directed to perform an inspection on phase B only. Upon disassembly, the interrupter was discovered to be loose and the oil color was very dark with poor measured dielectric strength. The failed operation of a major breaker was prevented, maintenance time was optimized in knowing what portion of the breaker needed service ahead of time, and an unplanned power disruption averted.

V. Conclusions

Digital electronic technology exists today that can monitor conditions such as arc extinguishment time, mechanism transit time, accumulated contact wear, the presence of restrikes, number of operations, and control circuit failure. Any of these can be used as a decision setpoint to implement the incipient breaker failure remedial techniques discussed in this paper.

On-line breaker monitoring provides intelligence about breaker condition to employ immediate remedial protection and control schemes for protection from incipient breaker failures and possible breaker failure clearing. Employing remedial protection & control schemes for incipient breaker

failure offers a way to improve power delivery by predicting incipient breaker failures, and avoiding breaker failure clearing. The suspected breaker may then be examined, refurbished if necessary, and placed back into service.

On-line breaker monitoring also provides intelligence about breaker trip and line fault conditions. Operators can identify and dispatch maintenance to alleviate “nuisance” tripping and other operations problems that can be routinely captured on breaker operations logs.

V. REFERENCES

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