Impact of breaker failure on stability electricity power transmission system

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Abstract— This paper presents the impact of substation breaker failure operation on system transient stability and the ways to enhance post-fault transient characteristics. Power System Analysis Simulation Package (PSASP) software is used to stimulate the circuit breaker failure operation in 220KV or 500KV substations. By stimulating all the possible line faults and their corresponding breaker failure conditions in Liaoning electric power grid, breakers that are most likely to cause system transient unstable are researched. Reasons of transient problems are speculated and implied, using equal area criterion. Different transient characteristics led by various fault types are compared. Also, measures that could help improve system transient stability are introduced and compared. Furthermore, a new method which is integrating Thyristor Controlled Series Compensation (TCSC) to the grid weak points is stimulated and verified. Results show that it could reduce generator angle fluctuation significantly.

Index Terms— Breaker failure operation, System transient stability, Equal area criterion, Tripping time reduction, Thyristor Controlled Series Compensation (TCSC)

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1 INTRODUCTION

Breaker failure protection is an important component of comprehensive system protection. Given tight stability margins and the opportunity for equipment damage during fault current conditions, a breaker failure scheme is needed to avoid delayed fault clearing from backup and remote overreaching protection elements. The impact of a breaker failure operation can be severe, however, and great care must be taken to avoid a misoperation of the scheme. A dependable scheme is important to prevent damage to high-value electrical assets. A secure scheme is important to prevent significant disruptions to adjacent power system components. Reliable detection of a breaker that has failed to operate when called upon that balances both dependability and security is key to the protection system. Traditionally, the state of the breaker is determined by one or both of two methods, electrical or mechanical. Electrical detection involves the detection of current flowing through one or more poles of the breaker. Mechanical detection relies on the physical status of an auxiliary contact (or contacts) that follows the action of the breaker contacts by way of a cam physically linked to the breaker mechanism. For reasons that will be discussed, electrical detection is the preferred method and is traditionally used in breaker failure schemes. Still, there are some applications where sufficient measurable current may not be present but detection of a failed breaker is required and action must be taken in a timely manner. One example is transformer protection that has no local breaker and relies upon a direct transfer trip (DTT) scheme to trip. The sensitive differential or sudden pressure elements could initiate a trip for a fault with currents below the threshold of sensing for the remote breaker failure relay. In these instances, mechanical detection has typically been added in parallel with electrical detection. While the addition of mechanical detection does extend the functionality of the scheme beyond normal fault current conditions, it is not an optimum solution because it introduces an additional point of failure that can have serious impacts. II. BACKGROUND Traditional breaker failure schemes initiate a timer based on a detected trip signal. Current detection is used as a supervising element either during the timing process or at the expiration and subsequent output of the timer. Current detection is used as an indication that the breaker has not opened or successfully interrupted current [1]. System configuration and time criticality dictate whether the current supervision is continuous (Fig. 1) or only at the expiration of the timer (Fig. 2). An instantaneous overcurrent (50) element is used to detect the presence of current above a set threshold. To add security to the scheme, this current threshold is typically set for a value indicative of a fault in the primary zone of protection and is often above normal load current seen by the breaker. This excludes scheme operation where a fault is not present. Breaker failures to open under load or no load are not usually considered time critical. There may be a separate scheme to detect this condition, or it may be left to operation personnel to detect and correct.

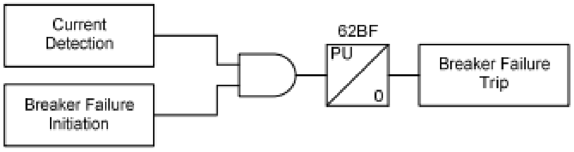

Fig. 1. Continuous Current Supervision Breaker Failure

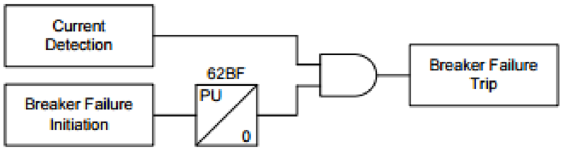

Fig. 2. Current Supervision at Timer Expiration

The application of breaker failure protection on a generator breaker requires an additional detection method beyond fault current detection. A large steam turbine generator shutdown requires a carefully crafted chain of events to occur in order to minimize possible damage or increased wear on the machine. The generator breaker is typically tripped by a protective relay detecting a reverse power condition. This is known as a sequential trip operation. The purpose of sequential trip is to ensure that the steam valves have actually closed and the turbine is no longer driving the shaft. This ensures that the turbine generator will not accelerate to excessive speed after it is disconnected from the power system. If the generator breaker fails to open as expected, the machine can be subjected to a motoring condition. While not instantaneous, this motoring condition has the potential to cause serious damage in a short period of time. Allowable motoring time for steam turbines is typically in the 30- to 60-second range [2]. The current involved in a motoring condition is dependent on the type of prime mover but, in all cases, is much less than the levels for which a fault detection scheme would typically be set. A steam turbine, for example, has a typical motoring power range of 0.5 to 3.0 percent of generator rating [2]. Assuming that the current transformer ratio (CTR) is chosen such that the secondary current is 5 A at 100 percent of generator rating, the current seen by the breaker failure relay for an antimotoring trip can be as low as 250 mA. In many cases, the CTR is chosen so that the secondary current is considerably below 5 A at 100 percent of the generator rating, making the relay current even lower

To overcome this, mechanical indication of the breaker status is added to the breaker failure scheme, as shown in Fig. 3. The breaker failure scheme can open additional breakers to effectively isolate the motoring generator in a timely manner to avoid damage.

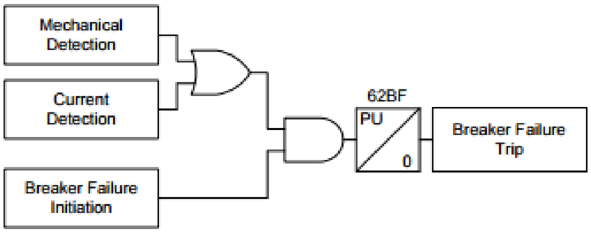

Fig. 3. Mechanical Breaker Detection Added

The mechanical indication is provided from one or more of the breaker auxiliary contacts. The breaker auxiliary contacts are typically provided from a rotating cam that is directly linked to the breaker mechanism. Contacts that have the device number 52a are provided that follow the state of the breaker (open when the breaker is open). Reverse contacts (52b) are also provided (closed when the breaker is open). Several contacts are usually provided and used in other parts of the protection and control scheme, such as local and supervisory control and data acquisition (SCADA) indication. Current flowing through the trip coil is usually interrupted by a 52a contact to limit potential thermal damage to the breaker trip coil and current interruption damage to relay tripping contacts.

II. DESCRIPTION OF DEFICIENCY

The addition of the mechanical breaker indication to the traditional current-based breaker failure scheme offers, in theory, the solution to no current or low current breaker failure detection. However, the mechanical indication through the breaker 52a auxiliary contact is not infallible. The indication is from a mechanical representation of the breaker status and is part of the element being monitored for failure. A breaker failure may involve a failure of the mechanism to move the contacts apart sufficiently to open the connection, while the auxiliary cam may move normally. In this case, the breaker failure to open would go undetected by the breaker failure scheme, leaving the generator vulnerable to motoring. Conversely, if the 52a contact fails to open correctly, a false failure can be indicated, resulting in an unnecessary backup trip, even though the main contacts have successfully interrupted the current. In most instances, a significant run of cabling is required to send the 52a indication to the breaker failure scheme. This cable also presents a possible point of failure for the scheme. Much like the mechanical linkage described previously, if the cable is damaged (either open or shorted), the same problems described for auxiliary contact failure will occur. The failure of this mechanical indication can result in an overtrip or a failure to trip of the scheme, depending on the mode of failure.

III. SYNCHRONISM CHECK AS A SOLUTION

A modern microprocessor-based synchronism-check (25) element is normally used to supervise the closing of breakers near a generator. Not to be confused with the automatic synchronizer device that matches the incoming generator speed and voltage and initiates closing at the slip-compensated advanced angle, the synchronism-check element prevents the breaker from closing if the two sides of the open breaker are not within a set band of angle difference [3]. The synchronism-check element supervision of the breaker closing offers an independent verification that the electrical systems being tied together are within a range to avoid any damage or adverse effects to the system or electrical equipment. Synchronism check is widely used on breakers across the transmission system and is not limited to generator breaker applications. In modern microprocessor-based relays, the synchronismcheck element has the ability to calculate slip between the two sides, in addition to the angle. Slip is the movement of the angle of one system relative to the other and is measured in hertz. The magnitude of the voltage signals used in the measurements for slip and angle must fall within upper and lower limits set to describe healthy levels on either side of the breaker.

IV. IMPLEMENTATION CONSIDERATIONS

The new breaker failure scheme is shown in Fig. 4. The traditional current-based breaker failure timer (62BF-1) is initiated by all protective trips that are accompanied by an overcurrent (fault) condition. It is supervised by current-based breaker status indication. A separate breaker failure timer (62BF-2) is initiated by all protective trips that can occur with low current (abnormal operating) conditions. To maximize security, this timer is supervised by three elements to indicate that the breaker has not opened: no slip, no angle difference, and no voltage difference. This second timer replaces the function of the 52a mechanical detection of breaker failure to open. Using a separate timer further increases security by allowing a longer time delay than is traditionally associated with clearing a fault from the power system. Implementation considerations of the new scheme are discussed further in this section.

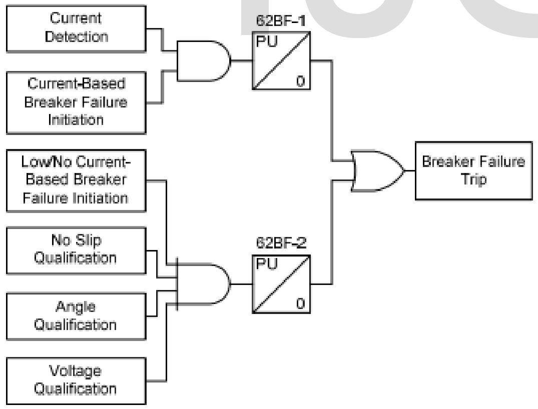

Fig. 4. New Synchronism-Check-Based Breaker Failure Scheme for Generator Breaker Application

A. Breaker Failure Initiate Considerations The addition of a synchronism-check element to an existing breaker failure scheme should be thought through sufficiently. Current-based indication of the failed breaker remains important for conditions where tripping is called on for a fault condition and fast clearing is required to minimize damage. Current detection remains a critical component of the breaker failure scheme. The synchronism-check indication is primarily for detection of a failed breaker when current is too low to measure reliably, namely during the unit shutdown process after the unit has been unloaded and the breaker has been tripped. The failure of the breaker to open at this time will lead to motoring of the unit, with relatively small currents involved.

B. Breaker Failure Timer Considerations Breaker failure time delays are typically set to balance damage or adverse effects to the system with security. Damage to a unit due to motoring is not instantaneous and occurs over time, depending on the type of prime mover. While speed is important, the time-delay settings can be extended for the synchronism-check breaker failure detection relative to the current-based breaker failure detection.

C. Voltage Signal Monitoring Considerations The voltage transformer (VT) signals become very important to the proper functioning of the scheme and should be monitored. The three-phase voltage signal for the generator side of the breaker(s) can be monitored by the loss-ofpotential (LOP) logic in the relay. However, failure of the single-phase synchronism-check voltage inputs can cause the scheme to fail to operate because the voltage on one side of the breaker would incorrectly be determined to be dead. The scheme is inherently secure for a failure of a VT signal

D. Bus Arrangement Considerations Bus arrangement is another consideration for breaker failure. Fig. 5 shows a straight bus unit connection where a single breaker is used to tie the generator to the system. In this arrangement, the scheme is straightforward. A synchronismcheck element connected to voltages on either side of the unit breaker detects slip as an indication that the breaker is open. If no slip is detected within the time delay set for the breaker failure operation following an initiating event, then the generator is cleared from the bus by tripping additional circuit breakers.

V. SETTING METHODOLOGY

A. Single-Breaker Example When the generator is tied to the system, there should be no calculated slip. The relay considered for this application has a dedicated status bit to indicate zero slip. This indication can be used to build supplemental breaker failure logic to improve the operation for a failure of the breaker to open. Additional consideration can be given to adding other identifying conditions seen in the values available in the synchronism-check relay to qualify the breaker failure and inherently add security. Fig. 7 shows the protection one-line diagram for the first settings example.

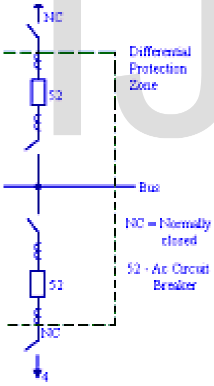

Fig. 7. Single-Breaker Application Example

B. Multibreaker Example Similar to the straight bus example, there should be no calculated slip when the generator is tied to the system. The same relay considered for that example can be applied in the multibreaker application with similar methodology. The significant difference in the multibreaker scheme is due to modifications to overcome the inherent selectivity limitation, discussed in Section V, Subsection C. Fig. 9 shows a protection one-line diagram of the multibreaker design to be considered for this example. This scheme is implemented using a dual-breaker relay that has breaker failure and synchronism-check functions for two breakers.

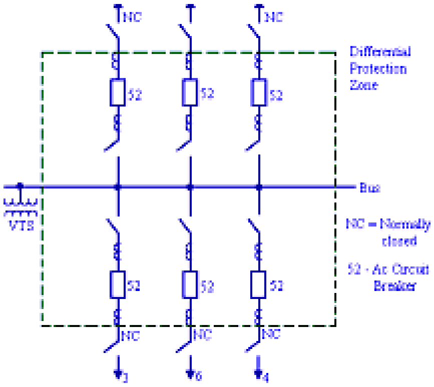

Fig. 9. Multibreaker Application Example

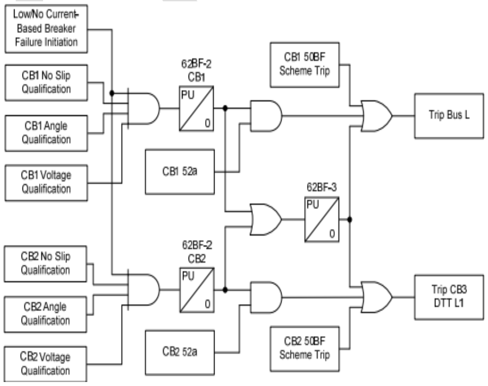

Fig. 10. New Breaker Failure Scheme With Sequential Tripping Logic

In this application, a change to sequential tripping to allow one of the two breakers to open under sufficient load to allow current-based open detection would help overcome the selectivity issue. If the first breaker fails to open properly, steps can be taken at that time to open additional breakers to isolate the generator from that side. Opening of the second breaker can then be done to disconnect the generator from the system with the synchronism-check-based open detection driving the breaker failure for the second breaker. As discussed previously, the initiation conditions must be properly considered to avoid a breaker failure operation for all but a shutdown sequence trip. Routine trips of one breaker should not initiate breaker failure via the synchronism-check logic because the generator is not intended to separate from the system

VI. CONCLUSIONS

Turbine generator protection involves many protection elements that detect abnormal operating conditions that, if not detected, can result in costly damage. Some of these abnormal operating conditions are accompanied by very low current flow through the generator breaker. Reverse power protection is one such protection element that is often used for normal shutdown of a steam turbine generator via a process known as sequential tripping. This scheme operates many times over the life of the system. Motoring a steam turbine generator while drawing only a few hundred milliamperes of secondary current in the relay circuit can cause significant damage to the turbine. The time to damage can be less than the time for an operator to detect and respond to a failure of the breaker to open. Traditionally, current detection has been supplemented with mechanical detection of breaker status using a 52a contact to detect a generator breaker failure to open condition. Mechanical protection can suffer from both dependability and security failure modes. This paper has presented a new breaker failure logic scheme that uses an electrical measurement to detect failure of a generator to separate from the system. It uses three measurements from a microprocessor-based synchronism-check element to detect when the generator has remained in synchronism with the system after being tripped

REFERENCES

[1] Y. Lee, A study on voltage collapse mechanism in electric power systems, August2000

[2] M. Stubbed, Simulation of voltage collapse, November 2001

[3] Ian Dobson, Robert J.Thomson, on voltage collapse in electric power systems, may 1999

[4] Bernard C.Lesieutre, voltage collapse, 1994

[5] A. Guzmán, C. Labuschagne, , "Reliable busbar and breaker-failure protection with advanced zone selection

[6] , Protective Relaying Theory and Applications. New YorkBasel: Marcel Dekker, Inc., 2011.

[7] Schweitzer Engineering Laboratories, Inc., Pullman, WA, 2006

[8] Manual, Schweitzer Engineering Laboratories, Inc., Pullman, WA,.

[9] D P Kothari, Power System Engineering

[10] Electric Power Research Institute, China. Power System Analysis Software Package, User-Defined Model & User Program Interface User's Manual

[11] Hu Yufeng, Yin Xianggen, Chen Deshu, Zhang Zhe. Research on protection

[12] Wang Yuhong. Introduction of Thyristor Controlled Series Compensation transmission technolog