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The Reliability of Breaker Failure Scheme for Transmission line Feeders

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Abstract

A Breaker Failure Relay (BFR) is designed to operate when the main protective relay sends a trip signal to the circuit breaker and the circuit breaker fails to trip. Then BFR trips adjacent circuit breaker on the bus. The BFR normally consists of 2 parts that are a fault detector and a timer in a separate hardware. This research presents an improved BFR with the two hardware parts combined. There is also a rearrangement of the DC schematic. These changes have been modeled with the logic and relay libraries in PSCAD/EMTDC. The simulation results show the improved BFR and the rearrangement of the DC schematic feasible. This was confirmed by the comparison of operating sequence and operating times.

The typical and improved circuit breaker failure models are evaluated with reliability technique. The comparisons of reliability results show that the improved circuit breaker failure scheme is reliable more than the typical one.

Index Terms : Breaker Failure Relay, PSCAD/EMTDC, Reliability

Nomenclature

These abbreviations are referred from The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition [1]. The following are abbreviations used in this research:

BFR: Breaker failure relay

50BF: Breaker failure current detector

62BF: Breaker failure timer

86BF: Breaker failure auxiliary lockout relay

BFI: Breaker failure initiate input

Introduction

A power system at the voltage level of 69kV or higher needs a local backup protection of circuit breakers (CB).

This is because the circuit breakers above 69kV have a higher failure rate. [1] If the circuit breaker does not trip after receiving a trip signal from the main protection, the fault current still exists. An engineer must design protection scheme to interrupt the fault current flowing to the failed circuit breaker. This is done by sending trip commands to all nearby circuit breakers in order to isolate the faulted section from the power system. The causes of the circuit breaker failure may be one of the following as Table I [2]:

TABLE I
CAUSE OF SF₆ CIRCUIT BREAKER FAILURE [3]

Percent (%)	Causes
43	mechanism failure
26	High volt component (CT, PT)
25	Electronics control & Auxiliary circuit
5	Other causes

The paper describes the fundamental of a breaker failure relay (BFR). The paper also shows the BFR operating procedures, models and DC scheme. One of the Electricity Generation Authority of Thailand (EGAT) Co. Ltd. 115kV substations was chosen as a primary circuit for the simulation. The secondary circuit was modeled using Continuous System Model Functions (CSMF) tools in PSCAD/EMTDC. The objective of the research is to verify the BFR model and the improvement of BFR scheme.

Breaker failure protection

The BFR normally consists of two separate hardware. These are a fault detector and a timer. BFR in EGAT uses an over current relay (50BF) with instantaneous characteristic as a fault detector and a timer relay (62BF) as a timer.

The operating procedures of a breaker failure protection scheme (Fig. 1) are [3]

1. Main protection operates and sends a trip signal (NO. or NC. contact) to initiate the BFR.
2. The over current relay (50BF) compares the fault current with its current setting. If the fault current is greater than the current setting, the over current relay sends a signal to initiate a timer relay (62BF).
3. The timer relay (62BF) starts counting. The trip time setting is normally less than the trip time of zone 2 setting of the distance relays at adjacent substations. This is to be assured that the BFR clears fault before the distance relays send remote trip signals.

It is important to note that the BFR must operate after main protection. BFR operates by sending a trip signal to a lockout relay (86BF). Then the lockout relay sends trip signals to all nearby circuit breakers. It also interlocks the circuit breakers to prevent a close signal.

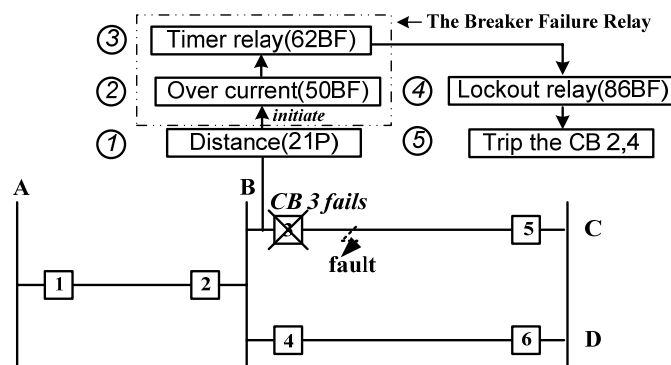


Fig. 1. Operation proceeding of BFR when CB1 fails

Network model in pscad/emtdc

The primary circuit was selected from EGAT's network. One of 115kV substations was chosen and modeled in PSCAD/EMTDC as shown in Fig. 2. The substation has four bays and bus scheme definition of main and transfer bus. They consist of transformer bay and three transmission line bays.

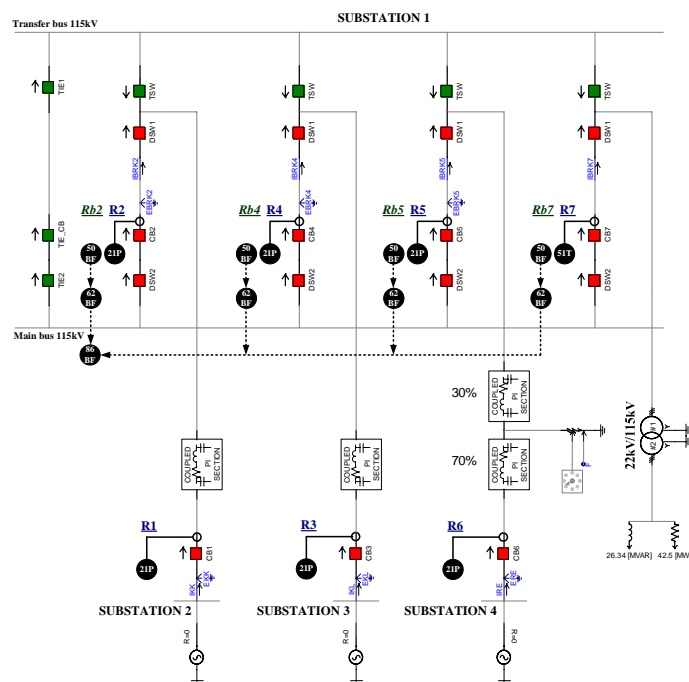


Fig. 2. Model of 115kV EGAT substation and protection system

Primary protective relay model

The 115kV substation model has two groups of important element. These are transformers and transmission lines. They need to be protected with relays. Transmission line and transformer protection were modeled and simulated as following;

A. Transmission line protection

Transmission lines are protected by distance relays to cover 85% of line length (zone1 protection). In this study, the distance relays were set to protect a three phase fault.

Fig. 3 shows the distance relay model. The distance relay obtains phase voltage and current. A FFT blocks separates phase and magnitude in order to prepare the input for the impedance calculation. The output impedance is in rectangular format (R and X). R and X are optimized for use with Mho relay.

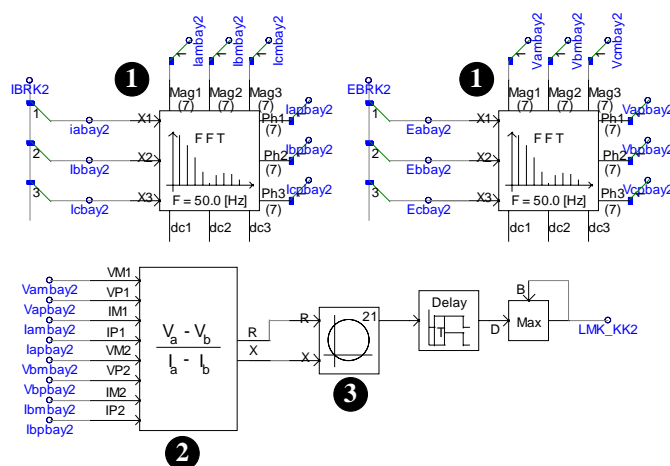


Fig. 3. The distance relay model

Where

- No. 1 = Frequency scanner
 No. 2 = Impedance calculation block
 No. 3 = Mho distance relay

B. Transformer protection

In practice, it uses many types of relays, for example, transformer differential, Buchholz relay, overfluxing relay and over current inverse time curves characteristic. In this paper, an over current blocks were selected for the simulation (Fig 4). They compare the input currents (phase currents) with the setting values. The relay will send the output logic signal when any of the input currents is more than its setting.

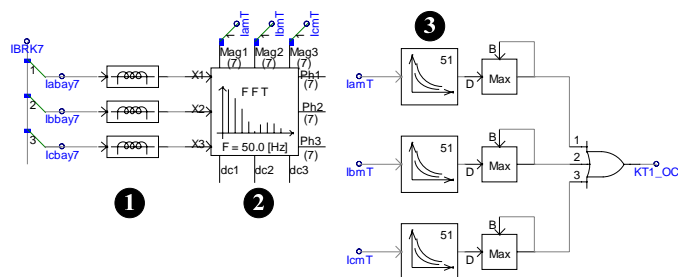


Fig. 4. Over current invert time curves model

Where

- No. 1 = Current transformer
 No. 2 = Frequency scanner
 No. 3 = Over current relay

Backup protective relay model

Fig. 5 shows a typical breaker failure DC schematic. If the breaker fails and the circuit breaker status (auxiliary contactor, 52A) still closes (circuit breaker can not trip), the both 50BF and 62BF relay operate in sequences. 50BF and 62BF will close to operate the lock out relay (86BF). The lock out relay will close the trip coils of all nearby the circuit breakers.

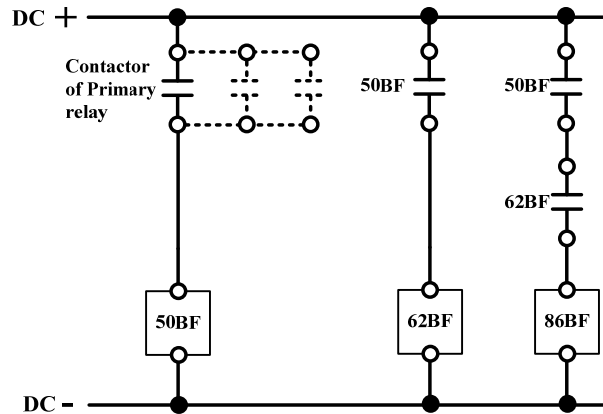


Fig. 5. A typical breaker failure DC schematic



Fig. 6. Basic BFR protection scheme

Fig. 6 shows a diagram of the basic BFR scheme in a sequential logic. The fault detector (50BF) and BFI (Breaker Failure Initiate) will operate the timer (62BF). The BFR model has two relay models that are over current relay instantaneous characteristic (50BF) and timer relay (62BF).

A. The fault detector (50BF)

The over current relay with instantaneous characteristic (50BF) can be modeled with a digital logic gate, a comparator and a multiplier block from PSCAD library as shown in Fig. 7. The setting value is a product between current setting multiplier (CSM) and I_n . The value of I_n depends on the secondary current setting of the main CT (5A or 1A).

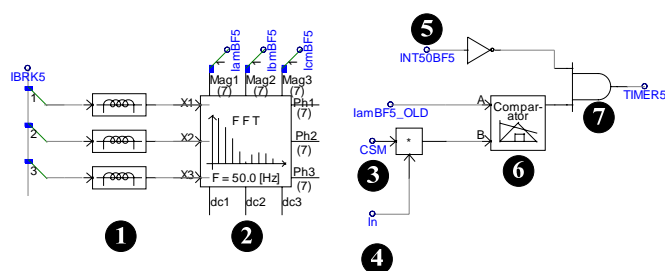


Fig. 7. Model of O/C instantaneous relay (50BF)

Where

No. 1	=	Current transformer
No. 2	=	Frequency scanner
No. 3	=	Current Setting Multiplier
No. 4	=	Rated current setting (1A or 5A)
No. 5	=	BFI input
No. 6	=	Comparator Block
No. 7	=	AND logic function

When a fault occurs on the transmission line No.3, the main protection (distance relay) sends trip signal to trip the circuit breaker (Breaker No. 5) and initiate BFI. The O/C relay (50BF) also detects the fault. If the circuit breaker can not interrupt the fault, it is considered as failure. The timer relay then operates.

B. The timer(62BF)

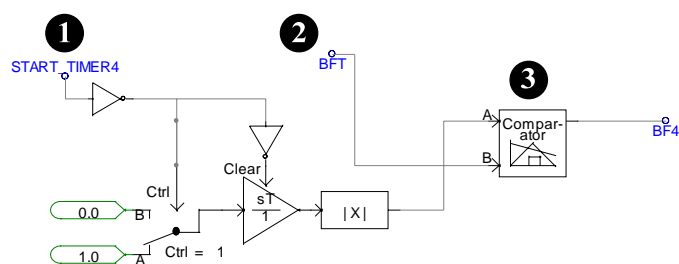


Fig. 8. Model of timer relay (62BF)

Where

No. 1	=	Timer initiate input
No. 2	=	Operating time setting
No. 3	=	Comparator Block

Fig. 8 shows the model of timer relay (62BF). The timer relay will start when it receives the output signal from the O/C relay (50BF). The timer is counting until it reaches the time setting.

While timer relay is counting, if the fault current is cleared, the timer relay will reset itself.

C. The improved BFR Schematic

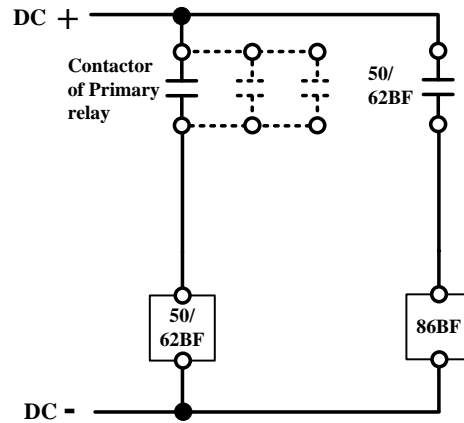


Fig. 9. The improved BFR scheme with integrated 50BF and 62 BF

The BFR DC schematic in Fig. 5 is normally used in EGAT. The fault detector and the timer were separated. The control circuit of the improved BFR can be described as a connection between the output from Fig.7 to start timer in Fig.8. The improved BFR DC schematic can be rearranged as shown in Fig. 9. With the same operating sequence, the difference between Fig. 5 and 9 are the number of auxiliary contactors and wiring.

Comparison of the operating time

The simulation was preceded with a three phase fault applied to transmission line no. 3 (Fig. 2) at 0.3 second. Setting zone 1 mho as main protection has a delay time of 0.1 second. The BFR as a local back up has a delay time of 0.3 second.

When fault occurs, the first case all circuit breakers are normal. The distance relay (main protection of transmission line no.3) will send the trip command signal in order to trip only the circuit breaker no.5 at $0.3+0.1 = 0.4$ second (Fig. 10) while the another circuit breakers still close.

However, if the circuit breaker no.5 fails to trip and the timer relay (62BF) set at 0.3 second. Then, all nearby circuit breakers will be tripped by the circuit breaker failure protection scheme at $0.3+0.1+0.3 = 0.7$ second as shown in Fig. 11.

For the improved BFR scheme, the result was illustrated in Fig. 12. It gives similar operating time when comparing with the typical BFR scheme.

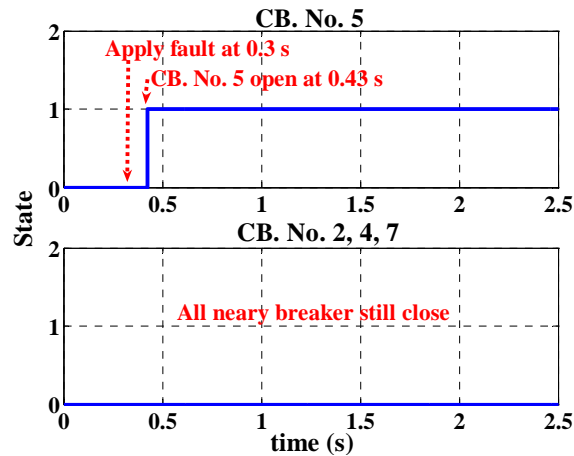


Fig. 10. The status of circuit breakers at substation 1, Where state 0 = CB. close, state 1 = CB. open
(All CB. are Normal)

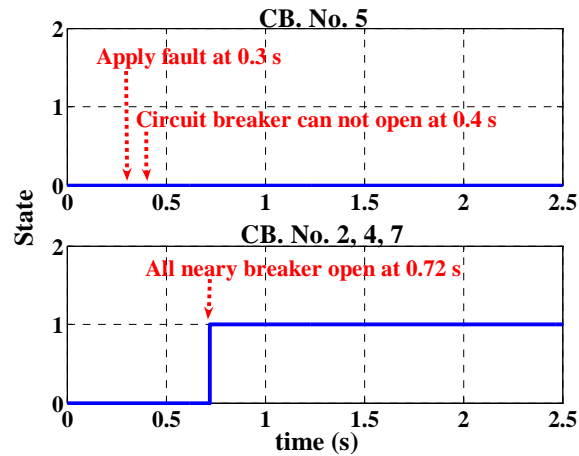


Fig. 11. The status of circuit breakers at substation 1, Where state 0 = CB. close, state 1 = CB. open
(Typical scheme)

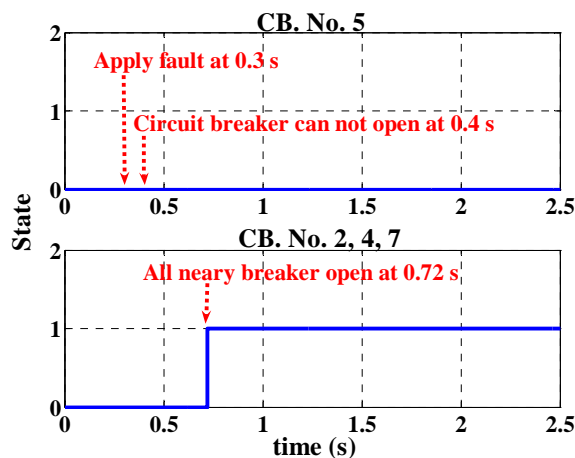


Fig. 12. The status of circuit breakers at substation 1, Where state 0 = CB. close, state 1 = CB. open
(Improved scheme)

Reliability model

In the protection system, the event tree is one technique for assessing the reliability. The term reliability can apply to protection system failure when considered in terms of dependability and security [4]. The event tree analysis is used to evaluate for research. The major advantage of event tree represents the sequential operation state of the system. In this section, both typical and improved circuit breaker failure protection schemes are modeled. They are represented in a reliability block diagram. To create the reliability model, each relay's components are considered with sequential operation.

Referring to Fig. 5, the typical DC schematic diagram of the circuit breaker failure protection scheme consists of two relays over current relay (50BF) and timer relay (62BF). The over current relay consists of a power supply unit, analog input unit, over current relay unit and digital output unit. The timer relay consists of a power supply unit, timer relay unit and digital output circuit. It is represented as a block diagram as in Fig. 13. The improved DC schematic diagram of the circuit breaker failure protection scheme has only one relay as shown in Fig. 9. It consists of a power supply unit, analog input unit, over current and timer relay unit and digital output unit. It is represented as a block diagram as Fig14.

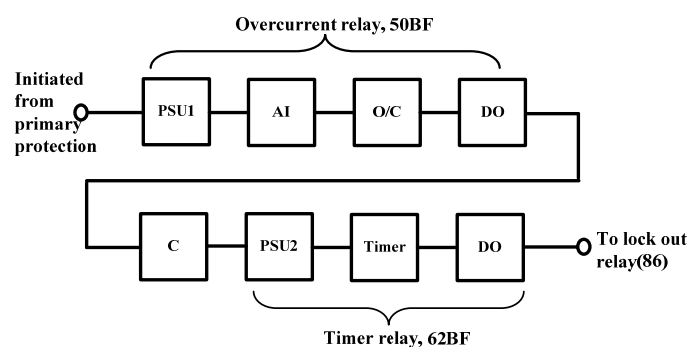


Fig. 13. The reliability block diagram of typical breaker failure scheme

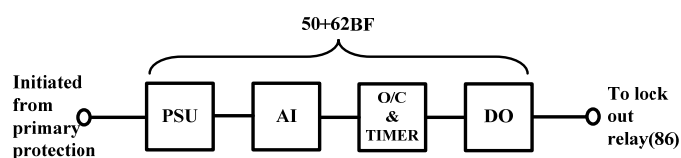


Fig. 14. The reliability block diagram of improved breaker failure scheme

Where

PSU1	=	Power supply unit for overcurrent relay
PSU2	=	Power supply unit for timer relay
AI	=	Analogue input
O/C	=	Overcurrent relay
Timer	=	Timer relay
O/C & Timer	=	Overcurrent and Timer relay
DO	=	Digital output function
C	=	Contactor and wiring

Consequence, both reliability block diagrams are created, the event tree for accessing the dependability for typical circuit breaker failure relay is illustrated in Fig. 13 and Fig. 14.

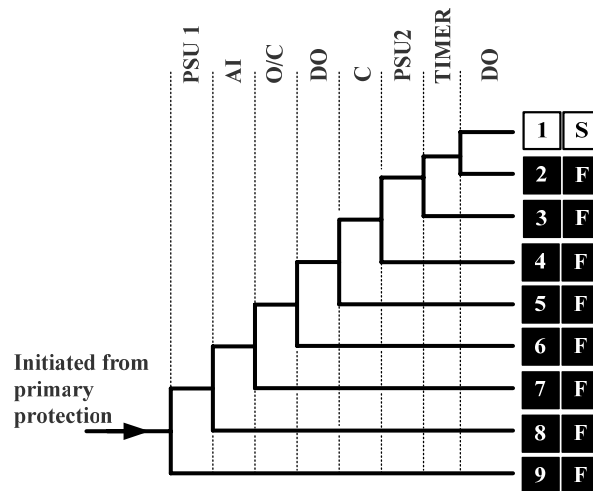


Fig. 15. The event tree of typical breaker failure scheme

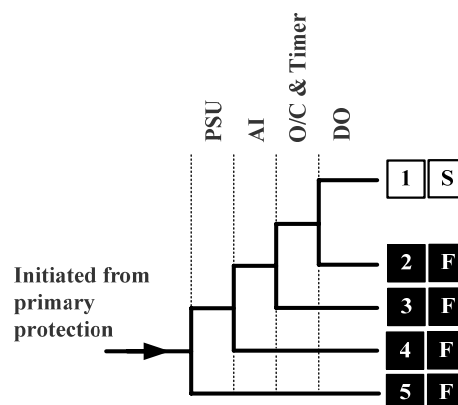


Fig. 16. The event tree of improved breaker failure scheme

When analyzing the dependability of both typical and improved circuit breaker failure protection scheme, the event tree defined in Fig 15 and 16 are used to derive the probability of possible outcomes:

S = Probability of operate successfully

F = Probability of fail to operate

Reliability data

The dependability model requires data on the unavailability of the various components. The examples of unavailability for the dependability model analysis for this research are predicted and illustrated following [4]:

PSU = 0.005, AI = 0.003, O/C = 0.001, DO = 0.004,

Contactors & wiring = 0.001, Timer relay = 0.001,

O/C & Timer relay = 0.001

Reliability results

Using the above reliability values the following results were calculated for dependability of both typical and improved breaker failure schemes. The summary outcomes of both circuit breaker failure protection schemes are illustrated in Table II.

TABLE II
SUMMARY OF PROBABILITY OUTCOMES

Outcome	Typical Scheme	Improved Scheme
S	0.97623	0.98795
F	0.02377	0.01295

Conclusion

The circuit breakers above 69kV have a higher failure rate. They need a local backup protection. The Breaker Failure Relay is a local back up protection and it normally consists of two separate hardwares. The paper has verified the BFR model and shown the improvement of BFR scheme. The simulation result operating time result when compare with normally BFR scheme shows that the improved BFR scheme gives the same operating time as the typical BFR scheme.

The advantages of the improved BFR scheme are obvious. First it is a combined hardware. This saves costs and installation space. Second the improved BFR scheme reduces the number of the contactors and wiring in the DC circuit.

Referring to the reliability result in Table II, the improved circuit breaker failure gives probability to operate successfully (S) more than the typical scheme.

References

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