BREAKER FAILURE RELAYING

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INTRODUCTION

Traditional breaker failure schemes have sensed the requirement for tripping a breaker, energized a timer, then initiated clearing of the breaker if current were not interrupted before the timer timed out. Using this concept, we have become dependent on consistent fast **dropout** of the overcurrent units used to sense this breaker current flow. This paper describes a new important concept that uses overcurrent unit **pickup** as the necessary ingredient for breaker failure clearing.

Another important topic examined in this paper is a method of detecting pole disagreement for a breaker. Breaker failure is of no less consequence if it occurs under non-fault conditions than if it occurs under fault conditions. The conventional breaker failure schemes only respond if the protective relays detect a fault.

THE NEED FOR BREAKER FAILURE PROTECTION

In backup protection techniques, it is not practical to have complete redundancy of all relay and breaker in the protection chain. For example, for some important protection systems, separate ac currents, ac potentials, dc supplies and redundant trip coils with separate connections for the primary and backup systems are used. Duplication of the major parts of the breaker (trip mechanism and interrupter) is impractical. Breaker backup must be provided by the tripping of other breakers. The breaker failure relaying scheme provides this backup protection by initiating the tripping of the minimum number of breakers necessary to clear the fault.

Since breaker backup must be provided by adjacent breakers, and the clearing of adjacent breakers may involve the loss of a large portion of the power system, it must be avoided unless absolutely necessary. An adequate time delay should be provided for normal interruption. This introduces a basic timer setting problem to the breaker failure schemes. The clearing of the backup breakers should not be faster than the protected breaker if the latter interrupts normally but should be cleared as fast as possible if the protected breaker fails.

TRADITIONAL PRACTICES

The basic approach of the traditional breaker failure scheme is shown in the flow chart and block diagram of figure 1 and figure 2, respectively.

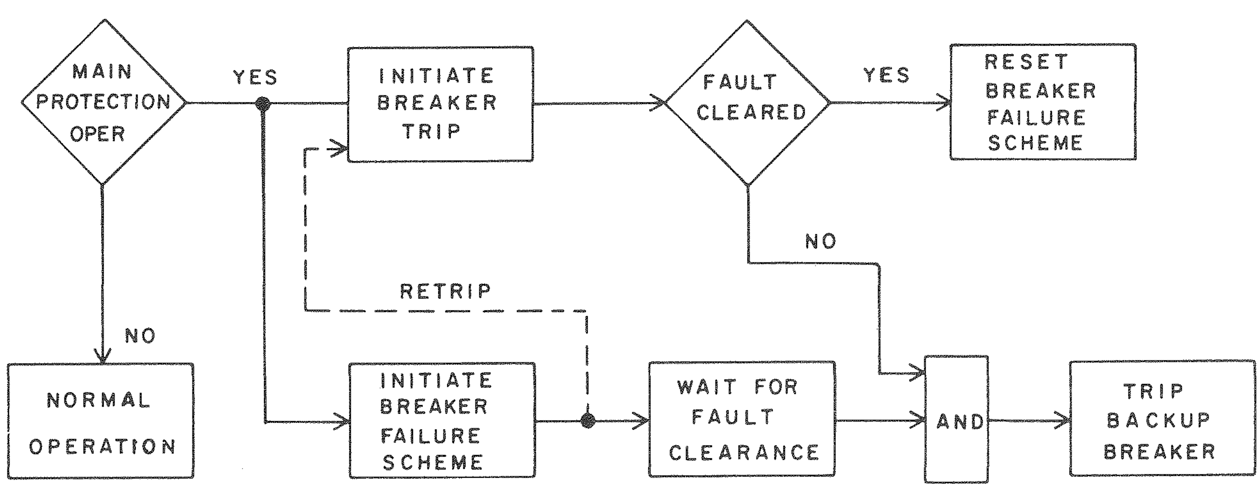

Figure 1. Flowchart of the Traditional Breaker Failure Scheme.

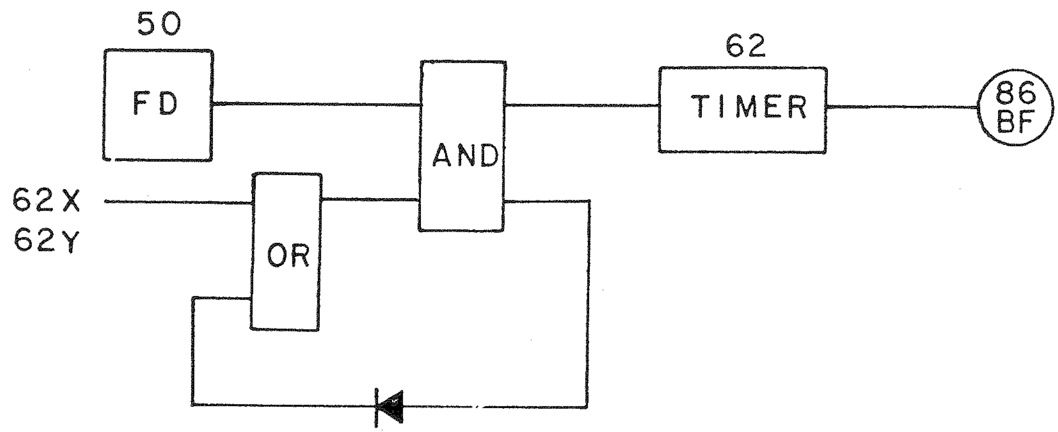

Figure 2. Block Diagram of the Traditional Breaker Failure Scheme.

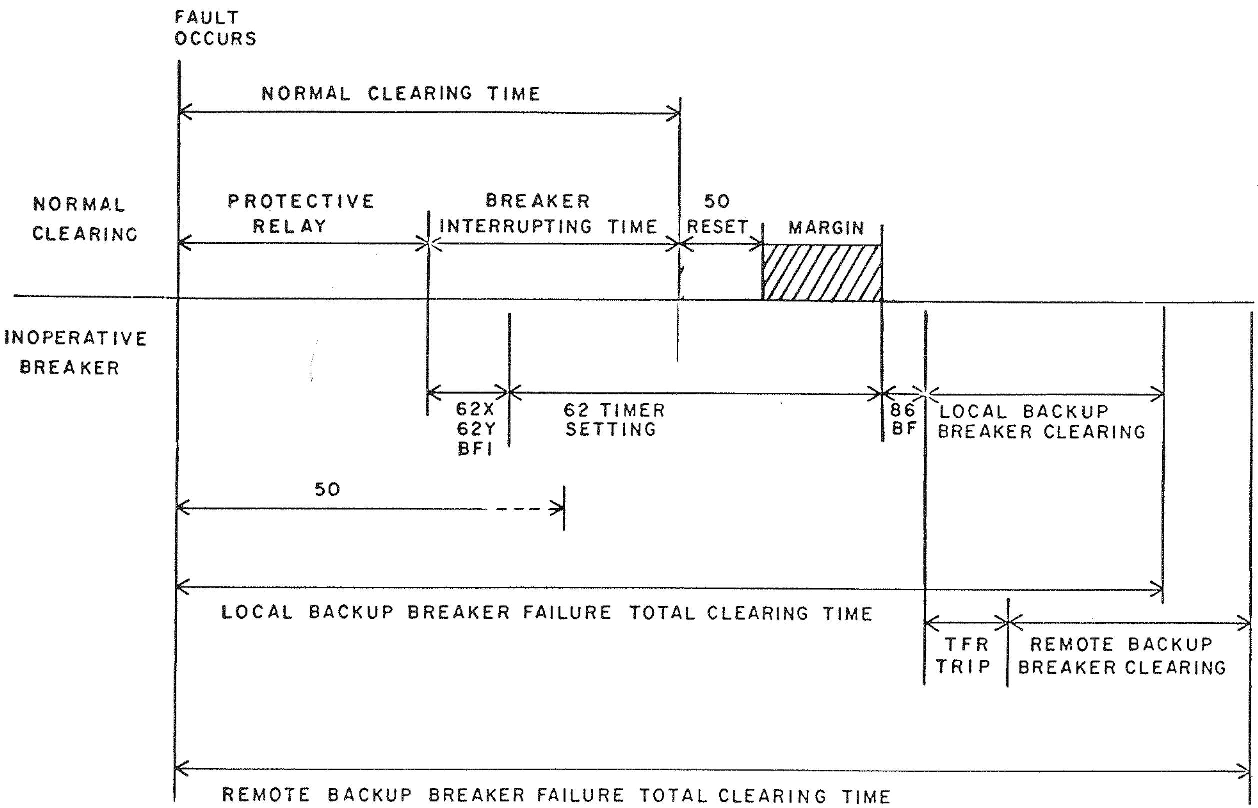

Figure 3. Time Chart of the Traditional Breaker Failure Scheme.

Refer to figure 2. The timer (device 62) is energized whenever the overcurrent unit fault detector (device 50) and the breaker failure initiation (device 62X or 62Y) are operated simultaneously. If the condition lasts for the duration of the timer setting, the lockout relay (device 86BF) is operated to clear the backup breakers.

The shaded time in figure 3, "margin" must have adequate duration to ensure security. This margin takes into account the following variables:

(1) Excessive breaker interrupting time
At low magnitude of fault currents, breaker interrupting time may be longer than those experienced at higher magnitudes. For example, the interruption may be one cycle longer for three cycle breakers at current below 25% of maximum rating (reference 2). Also, the interrupting time may be longer on close-open duty.

(2) Inconsistency in 62X, 62Y times
These are minimized by static breaker failure initiation. However, the wide time range associated with electromechanical BFI is primarily a function of variation in dc voltage. The BFI AR contact output in the SRU relay or ARM module (Uniflex) has an operating time of 3-5 ms. The BFI telephone relay in the SRU relay has an operating time of 8-16 milliseconds. The SG relay 62X/62Y in the KC-4/TD-5 scheme has an operating time of 33-50 milliseconds. The assumption is made that the pickup of device 50 will be at least as fast as the protective relay plus 62X, 62Y time. If this is not the case, the backup clearing time is longer and the margin is increased.

(3) Overtravel of the timer after device 50 reset

(4) Inconsistency in 62 timing

(5) Timer setting error
Considering human error, instrumentation error, etc.

(6) Safety factor
Because of the widespread harmful effects of a false 86BF operation, it is recommended that a generous safety factor be incorporated in the margin time. The degree of safety required is a direct function of the user's confidence level in all elements of the protective system. Two cycles safety factor appears to be adequate with 3 cycles being a widely used total "margin".

Refer to figure 2 the reset time of device 50 is a critical characteristic in the performance of the breaker failure system. It will affect the margin value as well as the 62 timer setting. Device 50 resetting **stops** the timer; with 62X 62Y seal-in, it is the **only** function that stops the timer (figure 2). It is affected by several factors:

1. Whether or not the current level after interruption is zero, the reset times are longer when the current after interruption is non-zero. Certain type of circuit breakers are equipped with arcing contacts and shunting resistors. When the main breaker contacts interrupt a fault, the current does not drop immediately to zero but to a level determined by the shunting resistor. It falls to zero when the arcing contacts open. The reset time of device 50 on such application may be longer.

2. The fault current level at which the unit is energized prior to interruption.

3. The setting of the unit.

   To prevent the device 50 reset time variables from affecting margin, it is usually recommended that the 62 time delay be determined for **maximum** device 50 reset time. Any faster 50 reset will then merely add to the safety margin.

   It should be noted that the longer the reset time of device 50 to be considered the longer the 62 timer has to be set. Consequently, it may be difficult to set the timer securely and still avoid system instability.

NEW BREAKER FAILURE SCHEME

Many approaches have been devised for improving the traditional breaker failure scheme such as using a shorter reset time of device 50 or using separate timers for different levels of fault current. These approaches will still be affected by the reset time of the device 50 and still present difficulties in determining the reset time especially when information on shunting resistor current is not available.

The new approach described in this paper is to use the pickup characteristic of the overcurrent unit instead of the reset characteristic as the significant ingredient for the scheme.

Figure 4 shows the basic concept of the new approach and figure 5 is the detail logic and typical external connections of the new static breaker failure relay type SBF-1, that uses this new approach.

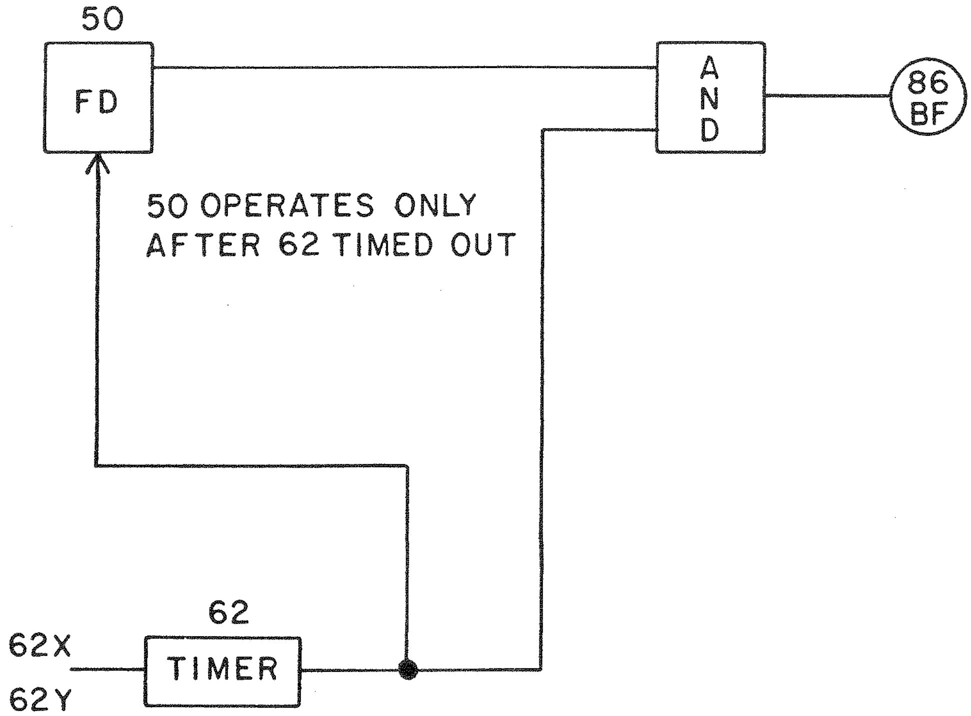

Figure 4. Block Diagram of the SBF-1 Relay.

The new approach has many advantages over the traditional ones:

(1) The device 50 will not operate before the 62BF is timed out, therefore, it will never operate when clearing normally and device 50 reset time is not a consideration.

(2) It permits shorter margin and shorter overall clearing times, and will give a net saving of 1-2 cycles over the traditional approach. This can be illustrated as below:

(a) Traditional scheme (figure 3)

Total clearing time = protective relay
+ (breaker interrupting time x 2)
+ max. 50 reset time
+ margin + 86BF . . . .(A)

(b) New scheme (figure 6)

Total clearing time = protective relay
+ (breaker interrupting time x 2)
+ margin + 86BF . . . .(B)

equ. (A) - (B)

(Saving in clearing time) = max. 50 reset time . . . .(C)

Equ. (C) shows that the saving in total clearing time equals to the device 50 max. reset time. The maximum reset time is one cycle for the ~~STU~~ SBFU relay and is 2 cycles for the KC-4 relay.

(3) The overall clearing time for the new scheme varies with fault current level. The higher the fault current, the faster the breaker failure clearing time. This is consistent with the requirements of system stability.

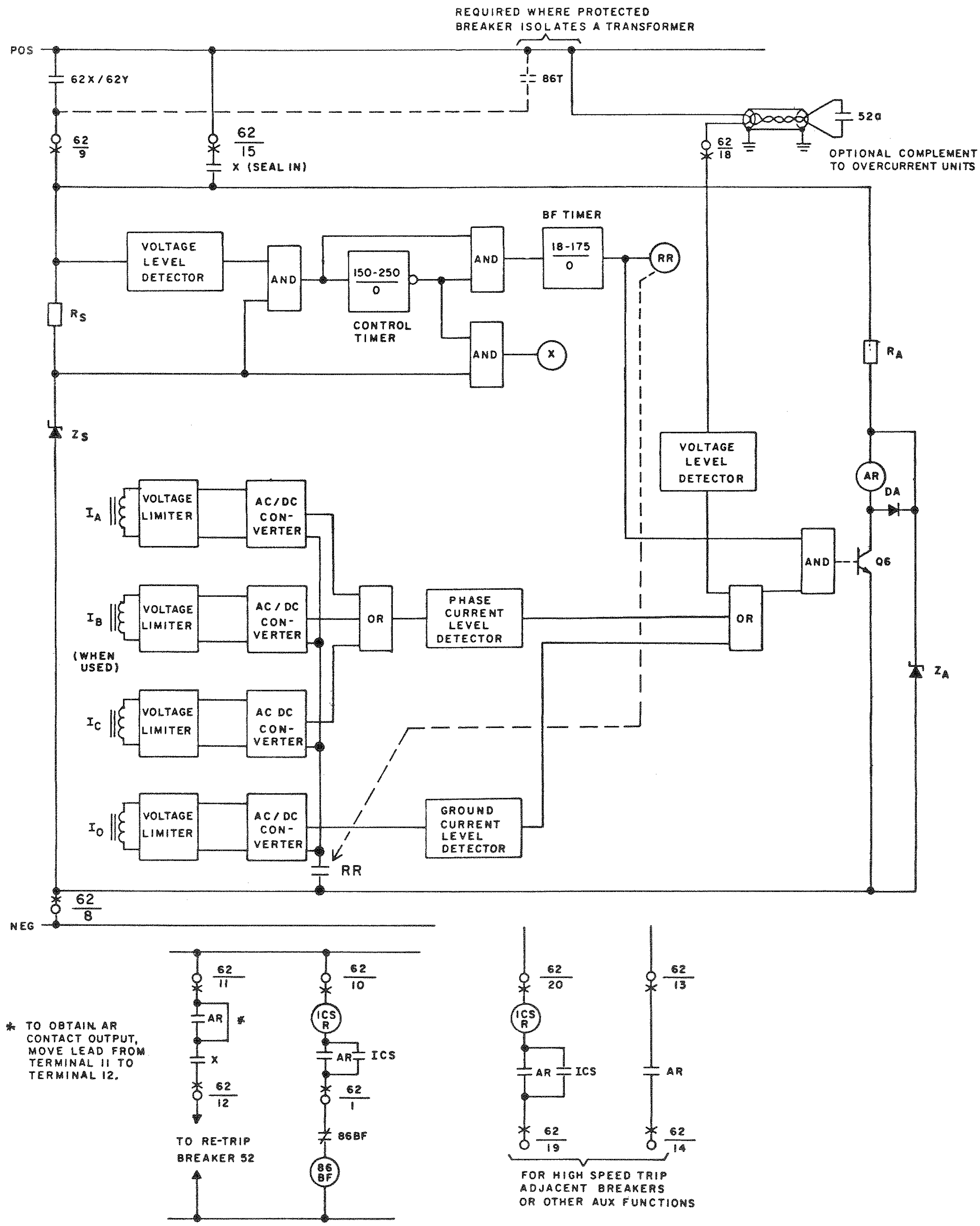

Figure 5. External Connection of SBF-1 Relay.

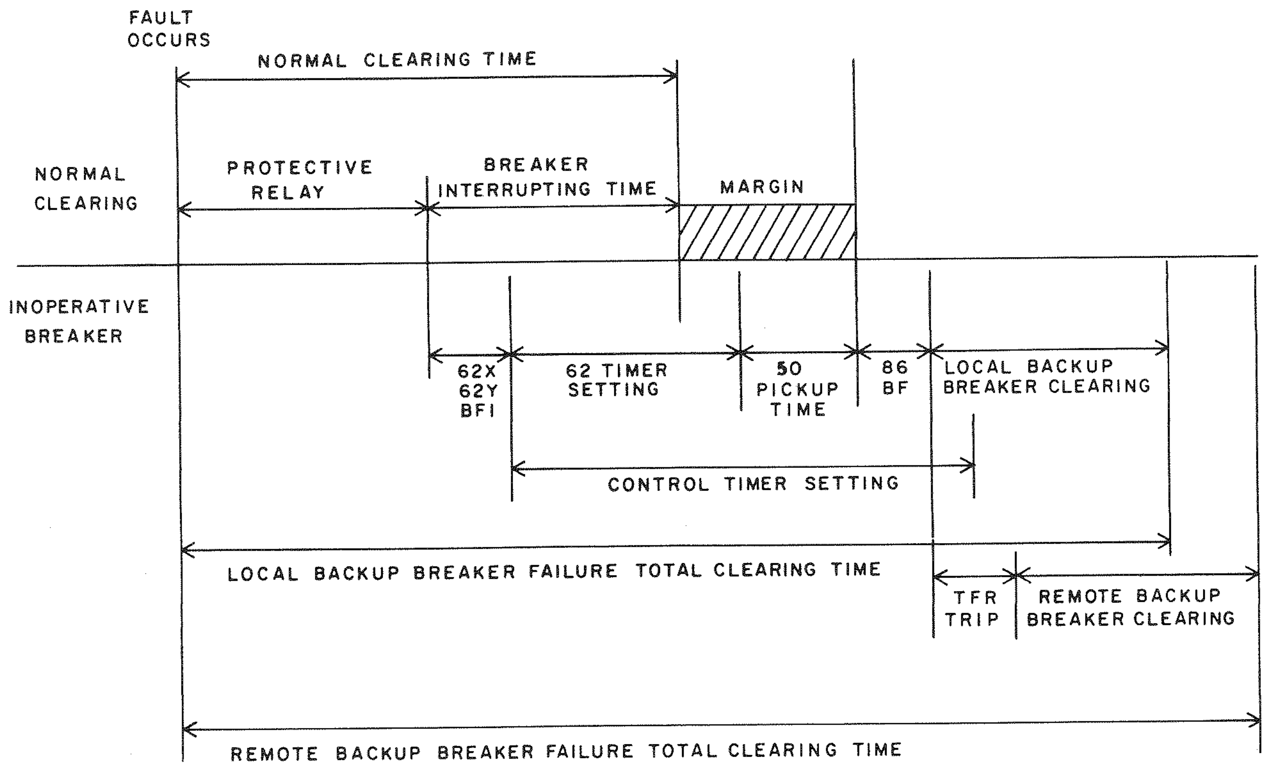

Figure 6. Time Chart of the SBF-1 Scheme.

The pickup time of the overcurrent units in the SBF-1 relay is 3-8 millisecond for fault current level from 2-20 times its tap setting.

(4) The overcurrent unit will never operate when clearing normally so it can be set lower than load current, if necessary.This avoids delayed tripping associated with low current until other breakers clear.

THE TYPE SBF-1 RELAY

The type SBF-1 relay is a solid state relay that uses the new concept for breaker failure protection. It contains three (or four) overcurrent sensing units and timers for controlling the sequence of action. Detection of a fault by a protective relay provides an input (by the 62X, 62Y, or BFI contacts) to the SBF-1 relay to start the adjustable ~~pickup~~ breaker failure timer, figure 5. Until timing is completed, the overcurrent units are restrained from operation. If current is still flowing following completion of the timing, the overcurrent unit operates and trips. Table 1 shows the major features of this relay.

SETTING OF THE TYPE SBF-1 RELAY

(a) **Overcurrent unit**

The phase units must be set below the minimum expected (ct secondary) phase fault current through the protected breaker, and the ground unit must be set less than the minimum expected $3I_0$ fault current.

Settings should be made to assure a multiple of pickup of at least 2 under minimum fault conditions.

Where the breaker contains a resistor that is inserted on tripping, the overcurrent fault detectors are set below the resistor current.

(b) **Breaker failure timer**

The breaker failure timer should be set to exceed the breaker normal clearing time by an appropriate margin. A secure margin for the SBF-1 is 2 cycles.

(c) **Control timer**

The control timer is for resetting the relay. It must be set at least 32 ms. (16 ms. plus the maximum 86BF time) longer than the breaker failure timer. The 16 ms. is based on the maximum pickup times of RR 50 and AR units in figure 5.

TABLE 1

Overcurrent unit range	O.5 to 13.5 amperes
Continuous rating	250 amperes for 1 sec.
Pickup time of o/c units	3 (min.) to 8 (max.) ms. for current level of 2X to 20X of setting.
Breaker failure timer	18 to 175 ms. continuously adjustable
Control timer	150 to 250 ms. continuously adjustable
Battery drain (125Vdc)	standby 0 timing 95 mA. tripping 130 mA.
Output	4 (N.O.) AR contact outputs, with 2 ICS, one telephone relay contact can replace an AR contact for **retrip** function.
Seal-in	Telephone relay contact seal-in for (1) BFI contact bounce, (2) Close-in 3-phase fault when memory action of the distance relay is decayed.
Voltage level detector	To restrain the relay from operating if dc supply voltage is below 60% of its rated value.

SOME SPECIAL BREAKER FAILURE PROBLEMS

BREAKER POLE DISAGREEMENT

At voltages of 345 kV and above, the physical size of the operating components and the phase spacing requirements of power circuit breakers have led to the the use of an independent operating mechanism for each phase. Also, with the trend to larger and larger turbine-generator sizes, system stability criteria have often dictated the use of independent pole operated breakers at voltages below 345 kV to obviate the three-phase fault, three-pole "hung" breaker fault condition. Rarely will more than one fail to interrupt fault current. Therefore, serious faults (those involving two or three phases) will always be downgraded if not entirely cleared, reducing the danger of system instability.

Field experiences have shown it necessary to consider the consequences of unsymmetrical operation of such a breaker. Electrical or mechanical failures have left one phase open when the others are closed, and vice versa. Since the pole disagreement may occur under no-fault condition, the breaker failure initiation circuit may not be energized. Therefore, the conventional breaker failure relay scheme will not cover the pole-disagreement condition. A type SLB relay, as shown in figure 10 and figure 11, should be used to cover this condition. Refer to reference paper 5 for the details of this problem.

UNEQUAL BREAKER CURRENTS

Double breaker terminals may experience unequal current distribution prior to the clearing of a sound breaker. Figure 7 illustrates this condition. If breaker B fails, for a traditional breaker failure scheme, the breaker B timer may not start until breaker A opens. This condition results in unduly long backup clearing time unless a shorter 62 timer setting or lower overcurrent unit setting is provided. However, the shorter timer setting or lower overcurrent unit setting may affect the security of the traditional breaker failure scheme. This problem can be eliminated by using the new approach, type SBF-1 relay, since the new scheme does not require the overcurrent unit operaton before the sound breaker trips.

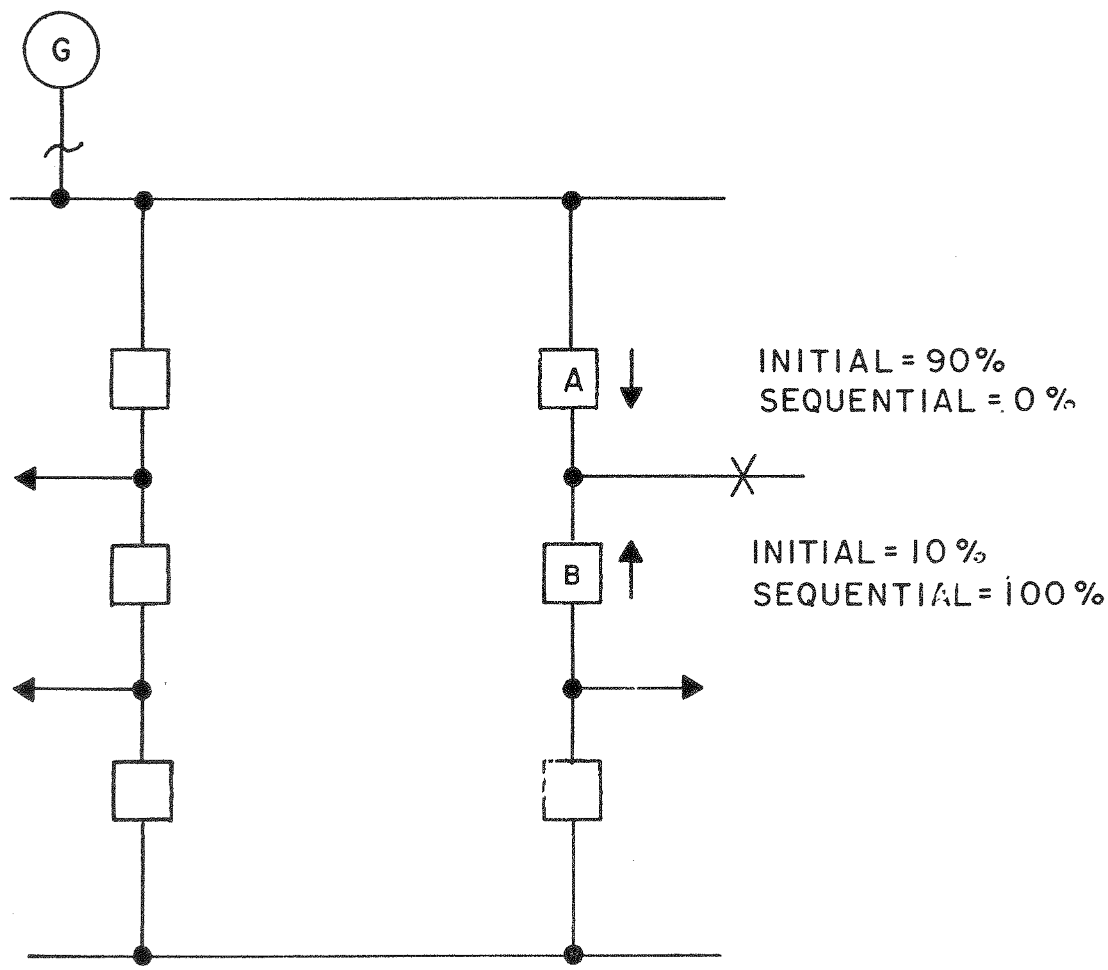

Figure 7. Breaker-And-A-Half System with Sequential Current Change.

WEAK SOURCE

Figure 8 illustrates the isolated weak source condition. When sound breaker 1 opens, the current from the isolated weak source, W, is not adequate to maintain the protective relay outputs, 62X and 62Y. This application requires the use of the 62X, Y seal-in circuit as shown in figure 5.

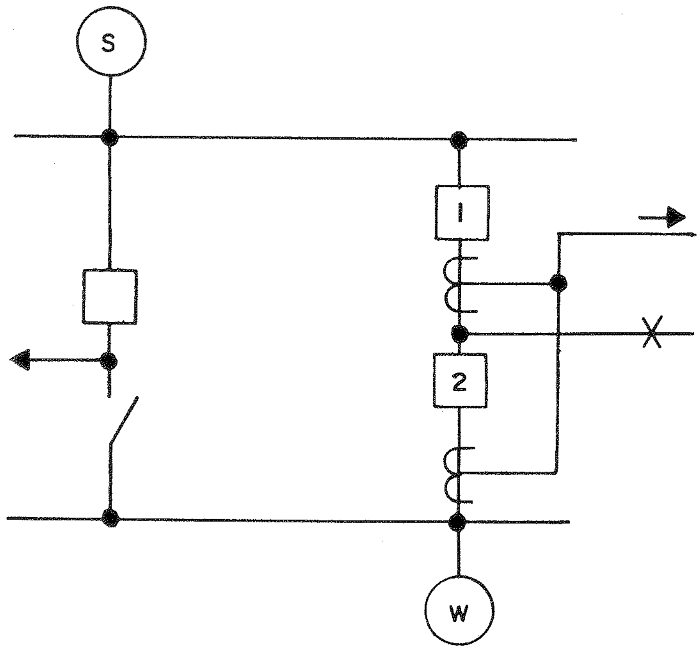

Figure 8. Example of Weak Feed Source Incapable of Holding up 62X or 62Y.

BREAKER CIRCUITS

Inherent in breaker failure is the possibility that the trip coil will remain energized and the mechanism not move. To avoid possible trip coil damage caused by inability of the 52a contact to open, it is advisable to use a back-contact of 86BF, the breaker failure lockout relay, to interrupt this circuit. The re-trip option of the SBF-1 relay will, of course, not be aborted by the presence of this contact. This provision cannot be included where a bus lockout relay is used as the breaker failure lockout relay because of the incompatible simultaneous requirements to trip and to open the trip circuit with the same relay.

Also, a contact of the 86BF relay should be used to block **all** closing of the breaker (automatic or manual). This assures that the cause of the breaker failure is examined and corrected and the 86BF is reset before closure is possible.

MULTIPLE BREAKER SCHEMES

Figure 9 shows a source of possible difficulty in breaker failure relaying in ring-bus and breaker-and-a-half systems.

If breaker A clears satisfactorily and B doesn't, large current, I_B through burden Z_R will apply voltage V_R across current transformer A. If V_R approaches the ANSI relaying accuracy class voltage (for example 400 volts for a C400 ct), the current in 50A can approach 10 amperes even though there is no current in breaker A.

The burden, current transformer quality and connection, and system configuration should be considered in choosing a breaker failure overcurrent relay setting. If it were set below the value in 50A above, false sensing of failure of breaker A would result for the case described.

BREAKER FAILURE AUXILIARY

The speed of the auxiliary BFI (breaker failure initiate) is not critical in any of the breaker failure relaying schemes is described here. Its operating time can be deducted from the timer setting. However, most users prefer to use a very high speed auxiliary relay and have virtually all of the time in the timer itself. There is wisdom in this. A 2 ms AR relay can be used instead of an 83 ms MG-6 relay. A 10% error in the expected operating time of the AR is 0.2 ms while the same 10% would be 8.3 ms in the MG-6. The timer on the other hand, is a refined, accurate timing device and will produce a lower total timing error using the faster relay for BFI.

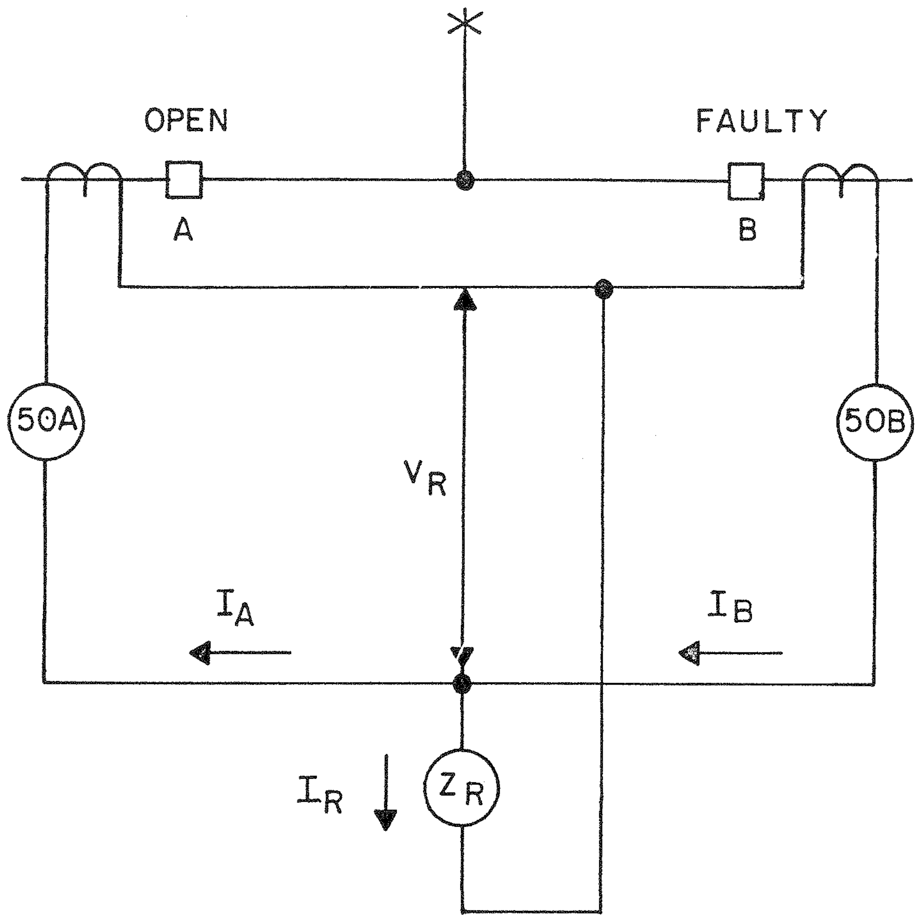

Figure 9. Example of Back-Feed to Breaker Failure Current Detector.

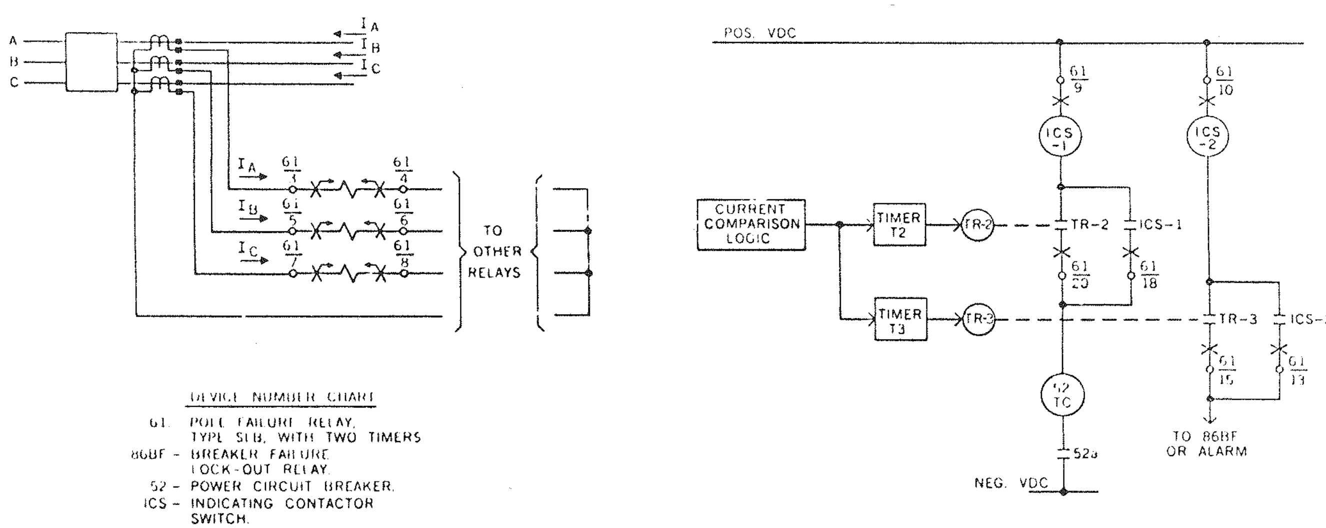

Figure 10. External Connections for SLB Relay with Two Timers.

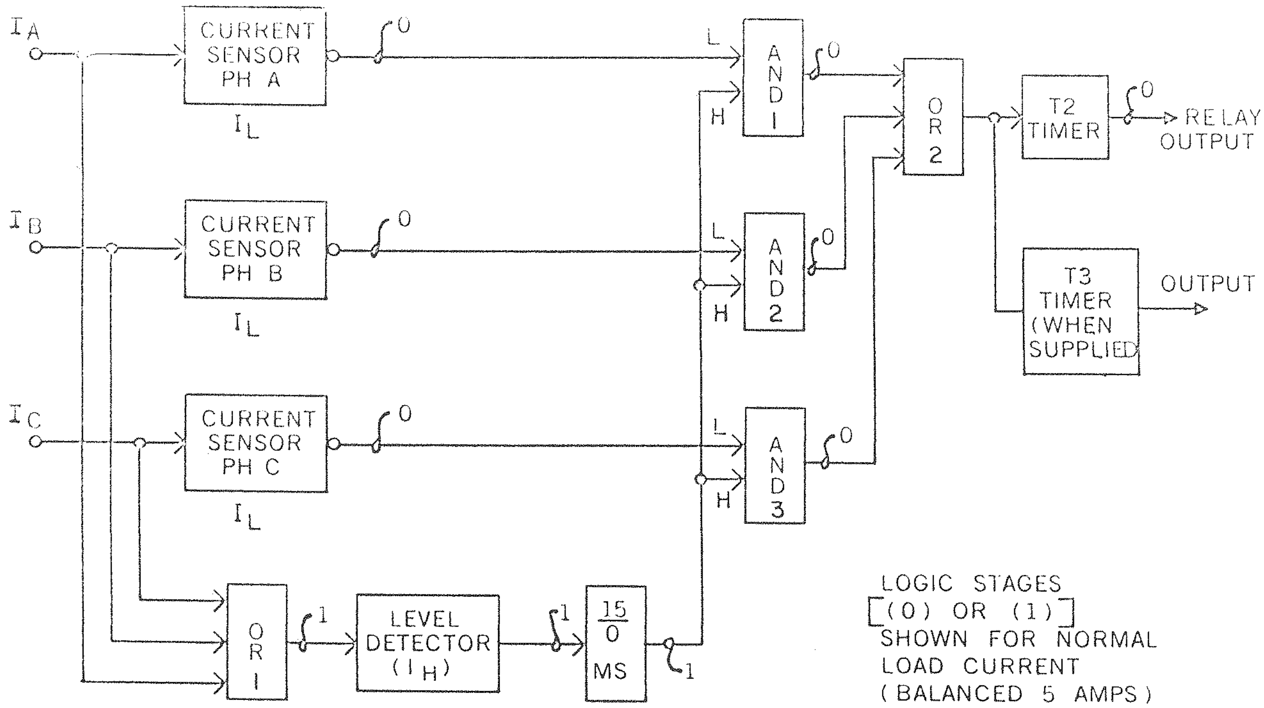

Figure 11. SLB Relay Logic Diagram

SINGLE POLE TRIP

Where a single pole trip scheme is used, breaker failure detection is complicated by the fact that phase to ground faults are cleared by opening one pole only. Load current continues to flow in the other two phases. During the open phase interval, a SLB relay would respond incorrectly. It should, therefore, not be used in this application.

CONCLUSION

This paper describes a new innovation in breaker failure relaying that should allow a **reduction** in trip times while achieving a **higher** degree of security. Other considerations are described that are pertinent to any breaker failure scheme but have received little amplification in the literature.

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