GET-8044

TLS1B Modular Relay System

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MODULAR RELAY SYSTEM

INTRODUCTION

The TLS1B protective relaying system is designed for use in virtually any application. As such, it has a number of features that will only be required in certain applications. The intent of this bulletin is to provide the following:

1. A description of measuring functions used in the system, and the features included in each.

2. A discussion of the applications where these functions and features might be used.

This bulletin discusses the schemes and equipment in general, but does not contain detailed information. This information can be fond in the following separate General Electric publications:

GEK-90621B - Transmission Line Relaying System with Two Forward Zones of Protection.

GEK-100559 - Transmission Line Relaying System with Three Forward Zones of Protection.

DESCRIPTION

The TLS1B protective relaying system can be applied on most transmission lines, including those with unique application requirements. Thus, one relaying system can be used to provide fast, reliable protection on long or short lines, compensated or uncompensated lines, double-circuit lines, etc. In all of these applications, single-pole tripping can also be implemented when required.

Single phase distance functions are used in the TLS1B. Each forward zone of protection uses three functions for phase faults (one for each phase pair) and three functions for ground faults (one for each phase). Two or three zones of protection can be provided and timers are included in the logic to implement time-delayed tripping. If independent zones are not required, the first zone function can be switched to second zone reach following a time delay controlled by the overreaching/third zone function. Two types of blocking functions are used in the TLS1B system. The blocking functions are required in all hybrid and blocking type schemes and must also be used in series compensated line applications. The first type of blocking function is a variation of positive sequence polarized mho ground distance function. Three such functions are used - one for each phase. The second type of blocking function uses negative sequence quantities operating into an amplitude comparator to form a directional function.

A common logic module is used to provide stepped distance protection plus the following pilot relaying schemes:

1. Permissive overreaching transferred trip/unblocking
2. Permissive underreaching transferred trip
3. Hybrid (weak infeed and channel repeat)
4. Directional comparison blocking
5. Zone acceleration.

The channel interface for each of the pilot relaying schemes is provided through contact inputs and outputs.

Line pickup circuitry (close into fault) is provided to insure tripping when closing into a bolted three phase fault. An additional line pickup circuit is supplied in single pole tripping schemes to insure tripping (three pole) when reclosing into a fault following a single pole trip.

Out-of-step blocking and an AC potential failure detection scheme are also included as standard features.

The TLS system is contained in a modular package consisting of two separate cases. The printed circuit boards, transformers, transactors and output relays are contained in pluggable modules. Multi-conductor cables provide the interconnections between the two cases. Each case includes two test/disconnect plugs, each of which has fourteen points. A single regulated DC-DC power supply module provides the DC supply voltages to both cases. The modular design offers the advantages of both reduced size and reduced cost.

MEASURING FUNCTION CHARACTERISTICS

Forward Reaching Functions

The forward reaching phase and ground distance functions use the variable mho function as the basic operating characteristic. This type of characteristic can be derived using a simple, two-input comparator as shown in Figure 1.

Although many such functions have been used over the years, there are some applications wherein a variable mho function using a two-input comparator might not provide the best overall performance. To

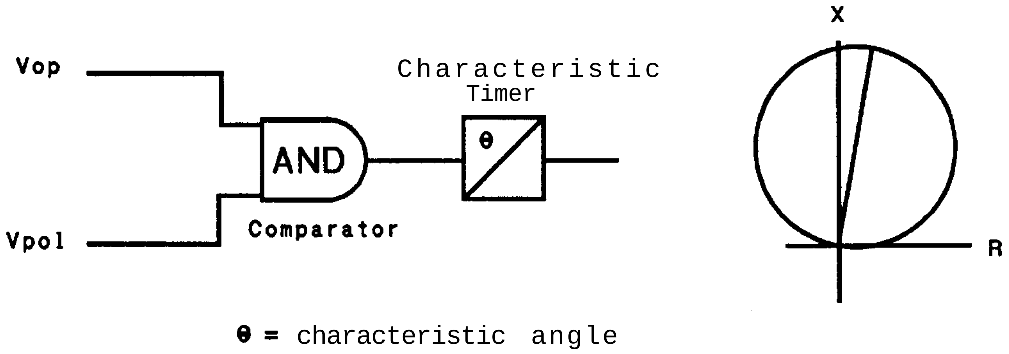


Figure 1 - Two Input Variable Mho

overcome the limitations imposed by these applications, other inputs are applied to the comparators used in the distance functions in the TLSlB. These inputs combine with those used to derive the variable mho function, and with each other, to form additional characteristics. Simplified circuitry for a multi-input phase angle comparator is shown in Figure 2. The phase angle measurement is made by comparing the coincidence time of all of the phasors applied to the comparator.

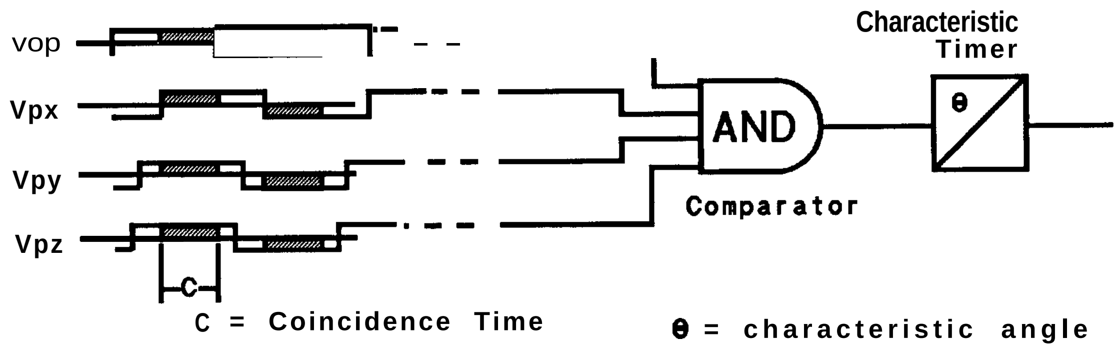


Figure 2 - Four Input Phase Angle Comparator

If all the phasors are coincident for a time corresponding to the characteristic timer angle setting, or conversely, if all of the phasors are separated by less than the characteristic timer angle setting, the function will provide an output.

The comparator input signals used in the TLSlB system and the characteristics that they provide are described below.

<u>Phase Distance Functions</u>

The following signals are used in the phase distance functions:

Operating Signal: VOP = Iϕϕ*ZR<u>/ϕZ1</u> - Vϕϕ

Polarizing Signals: Vpx = (Vϕϕ1 - Iϕϕ1*OFFSET*ZR<u>/ϕZ1</u>)M

Vpy = IϕϕZR<u>/ϕZ1</u>

where:
ϕϕ = AB, BC or CA
1 = positive sequence
ZR = relay reach
ϕZ1 = positive sequence reach angle
OFFSET = Forward offset in per unit
M = memory

Listed in Table I are the characteristics that are formed from these signals. The phase distance functions are always applied with all three characteristics in service.

TABLE I

CHARACTERISTIC	SIGNALS USED
Variable mho	VOP and Vpx
Reactance	VOP and Vpy
Directional	Vpx and Vpy

Ground Distance Functions

The following signals are used in the ground distance functions:

Operating Signal: VOP = **(Iφ - I0)ZR/φZ1 + K0*I0*ZR0/φZ0 - Vφ**

Polarizing Signals: Vpx = (Vφ1 - Iφ1*OFFSET*ZR/φZ1)M

Vpy **= Iφ2*ZR/φZ1**

Vpz = I0*ZR/φZ1

where:
φ = A, B or C
φZ0 = zero sequence reach angle
K0 = zero sequence compensation factor
0 = zero sequence
2 = negative sequence

Listed in Table II are the characteristics that are formed with these signals:

TABLE II

CHARACTERISTIC	SIGNALS USED
Variable mho	VOP and Vpx
Negative Sequence Reactance	VOP and Vpy
Zero Sequence Reactance	VOP and Vpz
Directional	Vpx and Vpy
Directional	Vpx and Vpz
Negative/Zero Sequence Phase Selector	Vpz and Vpy

The ground distance functions can be operated in the reactance mode by taking the variable mho (disabling the Vpx polarizing signal) out of service. When the ground functions are operated as reactance functions, they must be supervised by the overreaching functions that are required as part of the pilot/stepped distance scheme.

Reverse Reaching (Blocking) Functions

Two types of blocking functions are used in the TLSlB system.

The first blocking function is a variation of a positive sequence polarized mho ground distance function. Three of these functions are used - one for each phase. The following signals are used to derive this function.

Operating Signal:

$$VOP = -I\phi*ZR\underline{/\phi Z1} - K0*I0*ZR0\underline{/\phi Z0} - V\phi g + K(V\phi 1 - I\phi 1*OFFSET*ZR\underline{/\phi Z1})M$$

Polarizing Signal:

$$Vpol = (V\phi 1 - I\phi 1*OFFSET*ZR\underline{/\phi Z1})M$$

These blocking functions are designed to operate for all fault types, however, they may be slow to operate for some phase-to-phase faults. To provide for this contingency, a second blocking function is included.

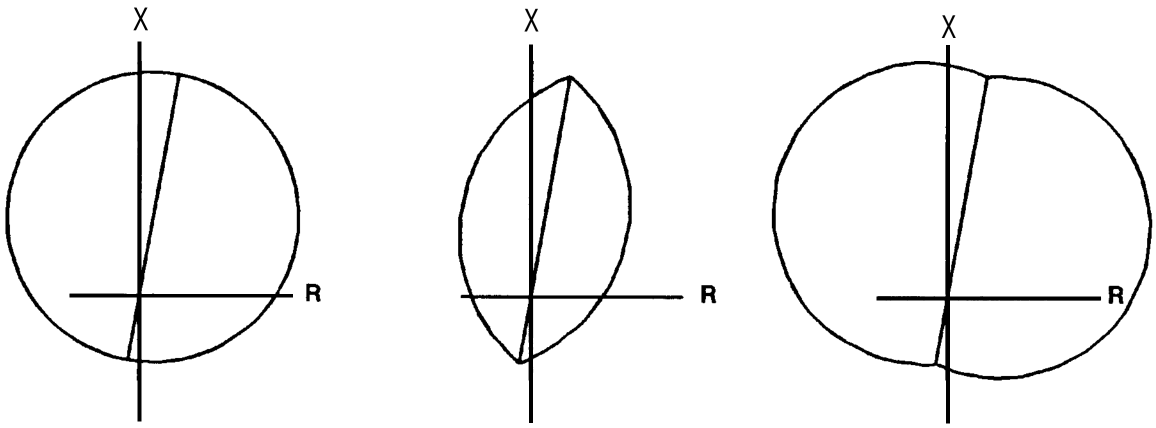
This second function uses negative sequence quantities operating through an amplitude comparator to provide a negative sequence directional characteristic. The signals used to derive this characteristic are as follows:

Operating Signal: $VOP = V2 + K*I2*ZR2$

Restraining Signal: $VR = I2*ZR2$

ADDITIONAL FEATURES

A number of other features are used to improve the performance of the functions. Following is a brief description of these features. Their use will be discussed at appropriate points throughout this bulletin.



a. Circle **b. Lens** **C. Tomato**

Figure 3 - Characteristic Timer Adjustment

Characteristic Timer Angle Adjustment

Adjustment of the characteristic timer allows the shape of the characteristic to be changed as shown in Figure 3, thus increasing the versatility of the function by allowing the area covered by the function to be easily changed.

Adjustable Phase Shift

Circuitry is provided in the voltage polarizing circuit (Vpx) of the phase functions that allows the polarizing signal to be phase shifted from its normal

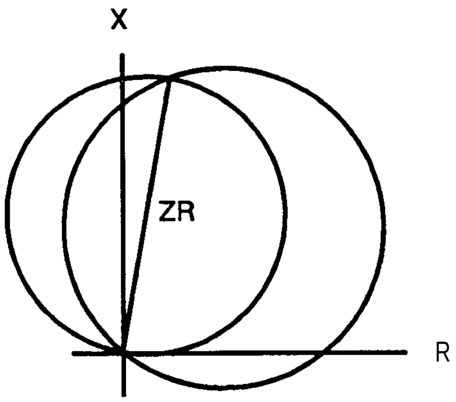


Figure 4 - Polarizing Phase Shift

position. The phase shift is made in the leading direction, and produces a change in the variable mho characteristic as shown in Figure 4.

Phase shifting circuits are also provided in the negative sequence (Vpy) and zero sequence (Vpz) polarizing signals of the ground distance functions. One effect of these shifts is to tip the negative or zero sequence reactance characteristic as shown in Figure 5.

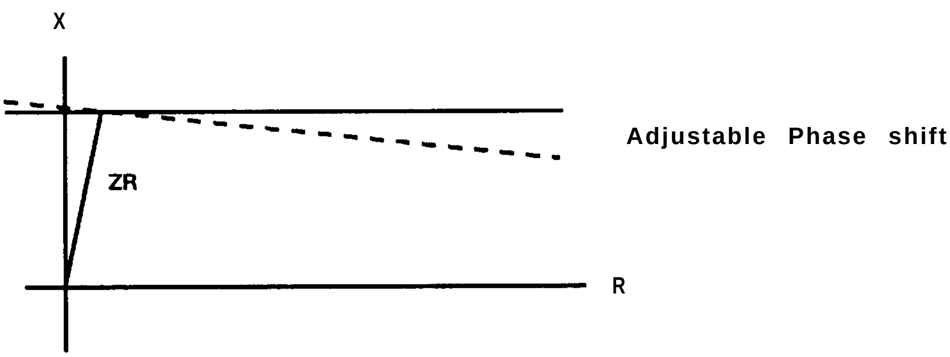


Figure 5 - Negative or Zero Sequence Reactance

Zero Suppression

The phasors of the operating and polarizing signals are converted to blocks before being applied to the comparator as shown in Figure 2. When zero suppression is used, the width of the blocks will be proportional to the suppression level setting as shown in Figure 6.

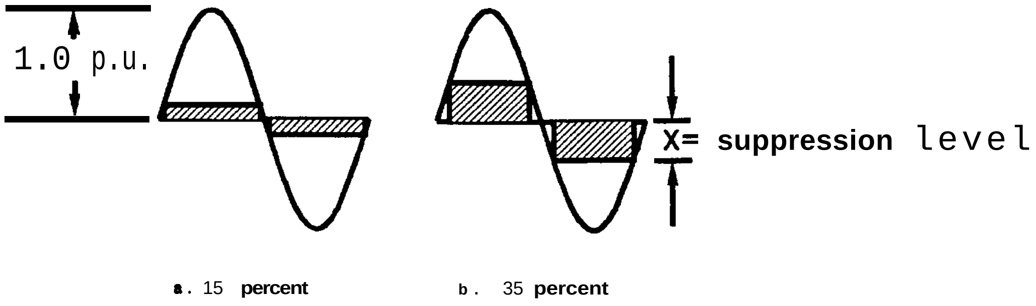


Figure 6 - Effect of Zero Suppression

For a given signal level, zero suppression reduces the width of the blocks as the suppression level is increased. Conversely, the width of the block will vary in proportion to the signal level changes if the suppression level is held constant.

Level Detector

The operate circuit in the forward reaching functions is equipped with an adjustable level detector that can be used to change the mho function into a hybrid distance/overcurrent function. With this feature in service, the operating signal must reach a preset level before the function is allowed to operate.

Zero Sequence Current Restraint (phase functions only)

The phase functions are provided with zero sequence current restraint that is designed to prevent them from operating during single line to ground faults, but to have little effect during double line to ground faults.

Fault Detector

A fault detector function is used to provide supervision of the trip outputs, and is intended to reduce the possibility of misoperation due to either potential or component failure. The function is a sensitive, high speed current operated function, that uses negative sequence current or the change of positive sequence current. It has an adaptive pickup level that is increased automatically, after a time delay, when a continuous input is applied to it. This feature is intended to prevent operation of the fault detector on negative sequence current caused by unbalances in the load current. The function will perform properly on low level fault currents because the adaptive feature is provided with a long time constant. If the fault detector function is not desired, it can be taken out of service via option links provided in the equipment.

Line Pickup (Close into fault)

Line pickup circuitry (close into a fault protection) is included in all TLS systems. Circuitry is provided for three pole and single pole tripping schemes.

The line pickup circuitry is implemented via current and voltage functions that operate through the logic to initiate tripping when energizing a line. Basically, the current and voltage functions are used to form open pole detectors to determine that the line is dead by sensing the lack of voltage and current. If a dead line condition persists for nine cycles, the logic is arranged to permit direct tripping by a positive sequence overcurrent function provided for this purpose. If there is no fault when the breaker is closed, the positive sequence overcurrent function will not operate, and the line pickup protection will be removed from service when all three phase voltages return to normal.

Similar type logic is used when single pole tripping is required, but in this case line pickup will only be energized during the period that the faulted phase is open. If a breaker is reclosed into a fault, three pole tripping will be initiated through the operation of the ground distance function associated with the faulted phase. If there is no fault, the line pickup circuitry will be removed from service following restoration of the phase voltage.

If the line pickup protection is not desired, it can be taken out of service via an option link.

Reclosing Control

Reclose initiate outputs are provided for three pole reclosing and single pole reclosing (when used). Option links are provided in the logic to block the reclose initiate outputs for any, or all, of the following conditions.

1. Operation of an external contact (via a contact converter)

2. Following a zone 3, or zone 2 and 3 time delayed trip.

3. Following a zone 4 time delayed trip.

4. Following an operation of any one of the MT functions, thus blocking reclosing for all multi-phase faults, but allowing reclosing for single line to ground faults (used in three pole tripping schemes).

5. Following a trip initiated by an out-of-step swing.

Sequential Reclosing

Sequential reclosing logic is provided in the TLS system. It is provided to control an independent recloser/reclosing system, and it may be used to prevent reclosing into a severe fault. The reclosing logic is arranged to recognize the severity of the fault by operation of certain of the tripping functions, and to provide an inhibit output to block reclosing at the terminals where those functions have operated. The inhibit output will persist until the line voltage returns to normal to indicate that the line is healthy. If a severe fault is not indicated, reclosing will be permitted at that terminal, and if successful, the voltage on the line will return to normal to remove any inhibit outputs that may have been produced. If none of the fault detectors indicate a severe condition, high speed reclosing will be initiated at all terminals of the line. If a severe condition is indicated at all line terminals, then reclosing will be inhibited at all line terminals. For the latter condition, reclosing will have to be performed manually, or a long time delay is often recommended to produce an automatic reclose and so minimize the shock to the system.

An inhibit output may be initiated for the following conditions:

1. Operation of any of the first zone functions within 0.4 cycle of the time that the fault detector operates.

2. Operation of any of the phase distance functions, thus inhibiting reclosing for all multi-phase faults on the line.

3. Operation of all three phase distance functions, thus inhibiting reclosing for all three phase faults.

Option links are provided whereby these features can be inserted/removed from service.

PT Fuse Failure

Circuitry is included in the TLS system to detect failure of a fuse in the potential supply of the system. The alarm circuit operates when all three of the following conditions are met.

1. Loss of any phase voltage.
2. Any phase current above the Iφ TRIP level detector setting.
3. No output from the fault detector.

The fuse alarm output is sealed in once it operates, and remains sealed in until all phase voltages return to normal. The output from the fuse failure alarm may be used to block tripping, sound an alarm, etc. The alarm will not operate if the phase current is not above the Iφ TRIP pickup, but the distance units cannot produce any tripping for this loss of potential because they are supervised by Iφ TRIP. If the current should then increase above the pickup level, the fuse failure circuit will operate before the distance functions, thus preventing any trip outputs. Note that the fuse failure alarm circuit will be blocked during a single pole trip when such tripping is employed.

Out-of-Step Blocking

Out-of-step blocking is provided on both the phase and ground overreaching functions. The ground functions are provided with out-of-step blocking to prevent operation of the ground overreaching functions in applications involving single pole tripping and parallel lines. With one pole open in one of the lines, it is possible for the ground distance function on the same phase in the parallel line to operate during a swing before the phase out-of-step blocking can be set up. The ground out-of-step blocking is set to prevent this. If single pole tripping is not employed, the ground out-of-step blocking is not required and is taken out of service.

APPLICATION CONSIDERATIONS

Because of the features described above, the distance functions are very flexible and can be applied with different characteristics to meet varying application requirements. They can be applied simply as a variable mho function, which will probably be preferred in most applications: or they can be applied as a hybrid distance/overcurrent function to give very fast operating time. They can be adjusted to optimize their performance on very long lines or on very short lines, and the ground distance functions can be applied in the reactance mode to provide increased fault resistance coverage.

Operating Time

The operating time of the distance functions can basically be related to the following:

1. The reach setting
2. The characteristic timer angle setting
3. The amount and type of filtering
4. The method in which the function is operated

The reach setting of the distance function helps establish the magnitude of the operating quantity (IZ-V), which in turn is instrumental in determining the operating time. This is so because large operating signals will either bypass the normal filtering in the function, or pass through the filtering much quicker than will signals of lower levels: i.e., the filtering becomes more effective as the signal level decreases in magnitude. Thus larger operating signals will tend to produce faster operating times than will signals of lesser magnitude.

Since the operating signal is dependent on current, voltage and reach setting, its magnitude will change as follows:

1. It will become larger as the fault is moved towards the relay location because the current will increase and the voltage will decrease.

2. It will become larger as the source impedance behind the relay location decreases.

3. It will become larger as the reach is increased.

The conclusion can therefore be drawn that the fastest operating time will occur for the most severe faults and that the operating time can be optimized by using the largest possible reach consistent with secure operation.

It was pointed out earlier that the shape of the characteristic could be changed by changing the characteristic timer angle setting. Longer timer settings produce more lenticular characteristics and minimize the effects of load flow. Unfortunately, longer settings also produce slower operating times. Shorter timer settings (tomato characteristic) will produce faster operating times, but will also increase the area of coverage and so increase the exposure to load flow. It might seem logical to use short timer settings on short lines where load impedance may be negligible, and in that way get faster operation. However, this is not a viable approach because the tendency to overreach will be increased and directional integrity may be jeopardized. It is possible to reduce the timer setting to get faster operation, but other steps must also be taken to provide secure operation in conjunction with the faster times. These steps are described next.

Filtering

A simplified diagram of the operate circuit for the distance functions used in the TLS system and the filtering used therein is shown in Figure 7.

In simple terms, the operate circuit can be thought of as being composed of three sections.

1. The high set (bypass) fixed level detector section

2. The Lo-Q, B filter section (with adjustable level detector)

3. The Hi-Q, A filter section.

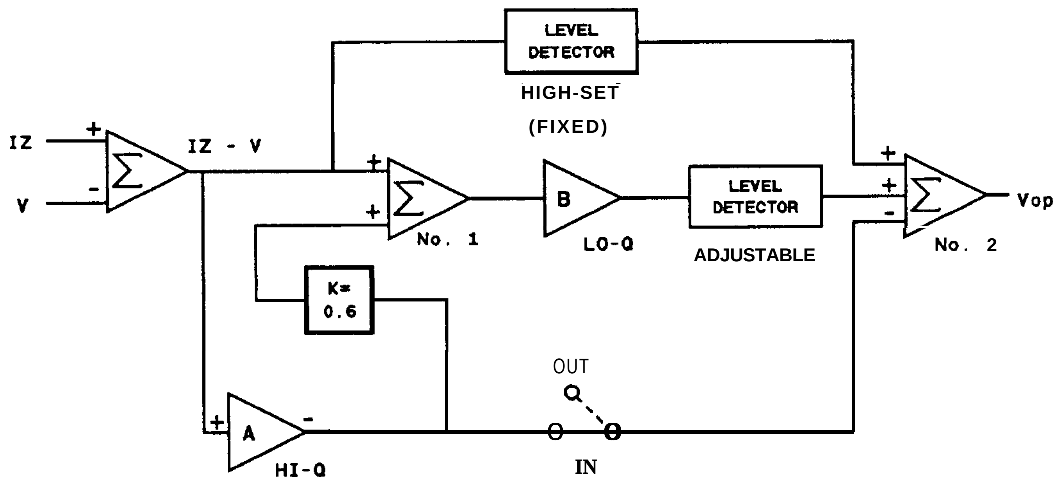


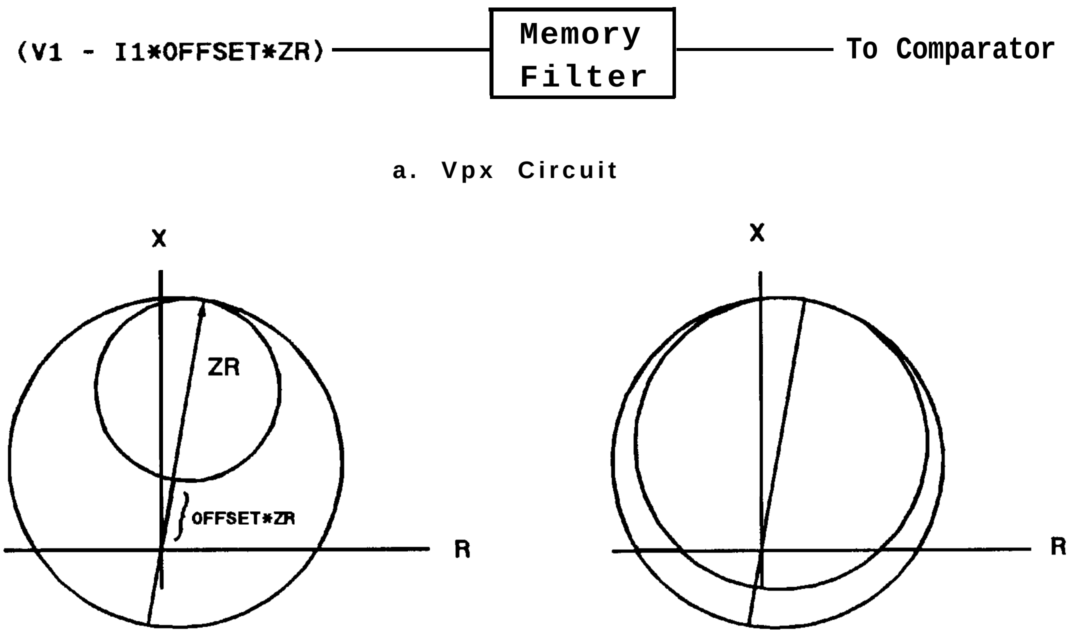
Figure 7 - Simplified Operate Circuit

The high set fixed level detector section allows the operate signal to be bypassed around the A and B filter sections for very high signal levels. In this way, faster operation is obtained because the normal filter delays are minimized. The high set level detector setting is fixed and has been empirically selected to eliminate the adverse effects of transients normally encountered on the power system.

With the A FIL link in the "out" position, the output of the A filter is removed from the number 2 summing amplifier. The A filter output is still used, however, to cancel a portion of the operating signal before it is fed into the B filter. On a steady-state basis, the B filter will see only 40 percent of the operating signal because of the output of the A filter. The intent here is to lessen the energy stored in the B filter. Now, when an internal fault occurs, the operate signal will pass through the B filter much faster because the signal will have less stored energy to overcome. Furthermore, at the inception of an internal fault, the output of the A filter tends to add to the operate signal during the first half cycle of input to summer number 1. This dynamic addition increases the magnitude of the operating signal, thereby permitting it to pass through the B filter even faster. Also, with the A filter out, and with the level detector set as proposed, the reach of the zone 1 functions can be increased beyond the normal settings. These modifications will reduce the operating time, but not to the extent possible. Further reduction in operating time can be achieved by reducing the characteristic timer angle setting, but forward offset and/or zero suppression must also be employed in the voltage polarizing circuit to provide security.

Forward Offset

Forward offset is produced in the voltage polarizing circuit and changes the characteristic by lessening the area of steady-state coverage as shown in Figure 8.



a. Vpx Circuit

b. Three-phase fault

c. Phase-to-phase (phase-to-ground and phase-to-phase-to-ground similar)

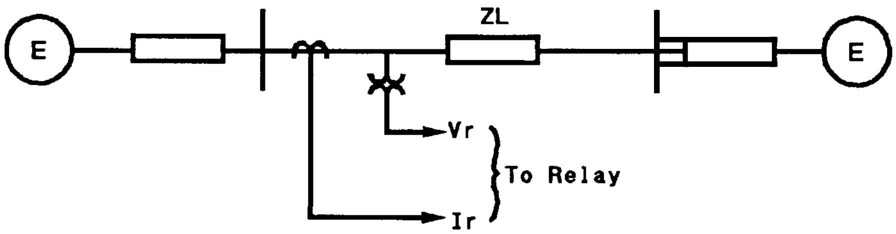
Figure 8 - Offset Mho Characteristic

The exact amount of offset will be a function of the fault type and fault current level.

For load flow and low level three phase faults, the offset will be equal to the offset reach, OFFSET*ZR. As the three phase fault level is increased, the offset will be less because of a clipping circuit in the function that keeps the offset voltage from exceeding a fixed level. Clipping is used to prevent the offset voltage from becoming so large that it would override the remembered voltage and cause the output of the memory filter to change so quickly that it would adversely affect the dynamic performance of the function. It is necessary to maintain correct dynamic performance so that the function will operate for faults within the shaded areas shown in Figure 8.

For unbalanced faults, the effect of offset is much less than that experienced for balanced conditions and the steady-state area of coverage is larger. This is so because the positive sequence voltage which is used in polarizing the function will be less affected during unbalanced fault conditions than during balanced fault or load conditions. Here too, the effect of clipping will become more pronounced as the fault current level is increased.

To summarize, offset is greatest for load flow conditions and becomes less for heavy faults and/or unbalanced fault conditions. Therefore, the effect of load impedance is minimized and the characteristic timer can be set with a shorter setting than normally would be used. As a consequence, faster operating times can be achieved but at the expense of steady-state coverage. The function effectively becomes a transient fault detector for some faults and the dynamic performance must be relied on for those faults when forward offset is used. There will, however, be no sacrifice in security. For example, consider the system shown in Figure 9.



CT = 3000/5

PT = 3000

ZL = $65 \angle 85$ ohms primary

= $13 \angle 85$ ohms secondary

ZR = $11.7 \angle 85$ (forward reach)

OFFSET = 0.4

OFFSET*ZR = $4.68 \angle 85$ (forward offset)

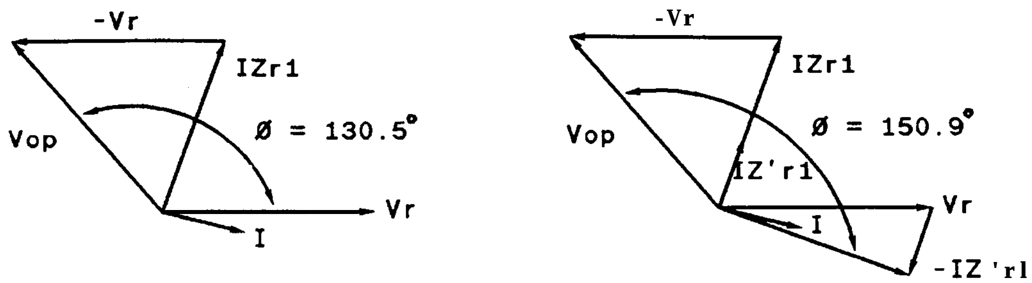
$I_r = 5 \angle 15$

$V_r = 67 \angle 0$ volts

Figure 9 - Simple Power System

For this system, the zone 1 functions are set to reach 90 percent of the line impedance, and an offset reach of 40 percent of the forward reach has been selected. In a typical application where very fast operating time is not required, the function would be applied as a variable mho without offset and with a characteristic timer setting of

4.2 milliseconds. Figure 10 shows the phasor diagrams for the non-offset and the offset mho function for the conditions of Figure 9.



a. Non-offset　　　　b. Offset

Figure 10 - Effect of Offset

Of interest in Figure 10 is the angle ϕ between the operating (Vop) and polarizing (Vpol) quantities. From this angle the coincidence angle (180 - ϕ), and hence the coincidence time, can be calculated. If a mho function is to be secure from the effects of load flow, a margin (M) of about two milliseconds should be maintained between the pickup time (P) of the function and the coincidence time (C) of the blocks produced with load flow: i.e., (M = P - C). For the phasors shown in Figure 9, the coincidence times are about 2.3 and 1.3 milliseconds for the non-offset and offset mho functions, respectively. Since the non-offset mho has a characteristic timer setting of 4.2 milliseconds, a margin of 1.9 milliseconds is obtained. If this same margin is to be maintained in the offset mho function, it can be achieved with a characteristic timer setting of 3.2 milliseconds. Thus, the offset mho function allows a shorter characteristic timer setting to be made without reducing the margin and hence maintaining the security of the function.

Zero Suppression in Polarizing Circuits

Zero suppression in the polarizing circuit also allows shorter time settings to be made, but in a different manner. Assume the same system shown in Figure 9, but that a zero suppression level of 35 percent is used, rather than an offset of 40 percent. The phasor diagram of Figure 10a still applies, and is shown again in Figure lla, but in sinusoidal form.

Figure 11b shows the effect of 35 percent zero suppression in the polarizing circuit. The effect is to reduce the coincidence time by approximately one millisecond so that the characteristic timer can be reduced accordingly, just as when offset was used. It must be noted that zero suppression also affects the steady-state operation of the function, and that the steady-state area of coverage will be reduced proportionately.

Although zero suppression and forward offset have similar advantages and disadvantages, they are different in nature and, depending on fault type, each affects the performance of the function differently.

Because the positive Sequence voltage polarizing signal will be less affected during an unbalanced fault than during a balanced three phase fault, the effect of forward offset and zero suppression will be much less for an unbalanced condition than for a balanced condition.

For three phase faults the amount of line not covered steady-state with forward offset is fixed at the magnitude of the offset (up to the clipping level described earlier). On the other hand, the amount of line not covered steady-state with zero suppression will depend on the source to line impedance ratio. The steady-state coverage will be practically non-existent for large source to line ratios, whereas practically all of the line will be covered as the source to line ratio gets very small. It is preferable to use zero suppression in applications involving small source to line ratios, whereas forward offset is preferred when the source to line ratio is large. In summary, forward offset and/or zero suppression can be used to reduce the coincidence angle of the inputs to the characteristic timer during load flow and so allow the timer angle to be reduced while still maintaining a secure margin. With this reduced timer setting, with

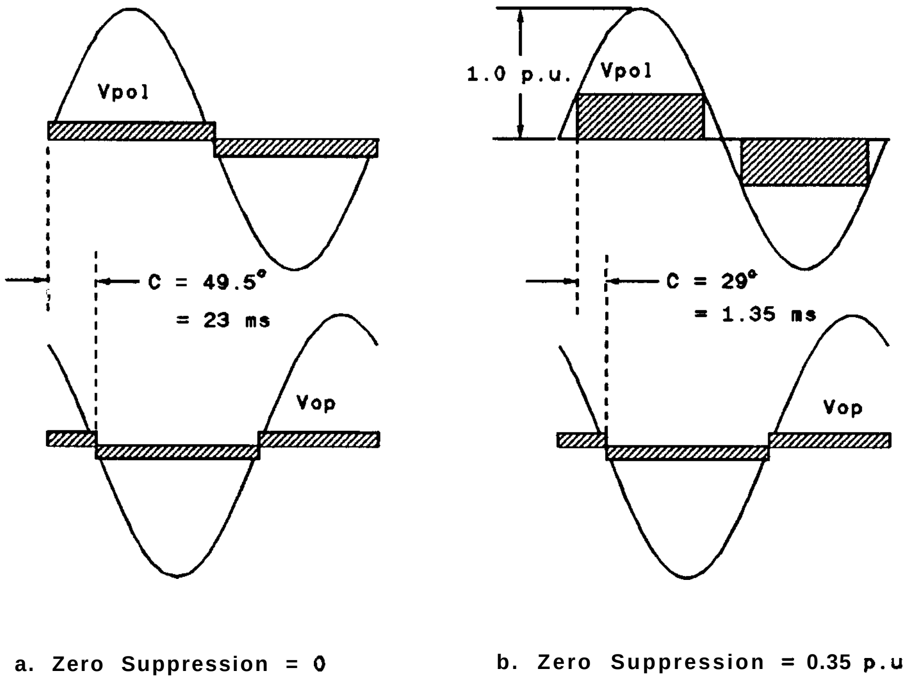


Figure 11 - Effect of Offset - Sinusoidal Form

the A filter out, and with the reach and level detector set as proposed, very fast operating times can be achieved for heavy faults close to the relay location. The following times were measured on the Model Power System Simulator (60 hertz times; multiply by 1.2 for 50 hertz times).

A. 4 milliseconds for three phase faults.

B. 4-8 milliseconds for single line to ground faults.

If very fast operating time is not a requirement in the application, the variable mho function characteristic should be employed to provide maximum steady- state coverage. To operate as a variable mho, all three sections of the operate circuit are used. With this configuration, the output of the A filter tends to dominate at the input to summer number 2 by virtue of its high Q and stored energy. This prevents the output of the A filter from changing too quickly during the dynamic period immediately following a fault. When the A filter is used, the level detector following the B filter is set equal to 0.1 per unit voltage to prevent operation on capacitor voltage transformer (CVT) transients. Note that CVT transients will be innocuous with the A filter out because of the high level detector setting in the B filter section. The fixed high set level detector will still be active and it will provide an improvement in operating time for the more severe faults, but still not as fast as that obtained with the A filter out.

Arc/Fault Resistance

In discussing the effect of resistance in the fault on the performance of a distance function, it is necessary to also consider the type of fault.

In faults not involving ground, the resistance is made up of the arc products. It is generally accepted that the voltage drop across the arc is constant and equal to about five percent or less of normal system voltage. The resistance therefore, is non-linear and inversely proportional to the magnitude of the total fault current. A rough approximation is to assume that the arc resistance is equal to about five percent of the impedance from the fault to the source behind the distance function (see Figure 14).

In faults involving ground, there is a linear component of resistance in addition to the non-linear component introduced by the arc. This linear component may be introduced by tower footing resistance, ground wire resistance, trees growing into the line, etc. For ground faults, therefore, the voltage drop across the fault resistance will not be fixed, and will be directly proportional to the total fault current. The linear component can be quite large, such as when a tree touches a conductor at mid-span, and may prevent any type of ground distance function from operating. For this reason, other forms of relaying, such as negative sequence directional overcurrent functions, are often used for ground fault protection.

For a homogeneous system with single-end infeed, the resistance seen by a distance function appears to be purely resistive; i.e., there is no reactive component and the resistance adds to the line impedance as shown in Figure 12a. On a double-ended system, the effect of load flow causes the fault resistance to appear to also have a reactive component as shown in Figure 12b.

Another effect of infeed is to magnify the resistive drop for ground faults because of the linear component of resistance, whereas the resistive drop for phase faults will be unaffected by infeed. Thus as

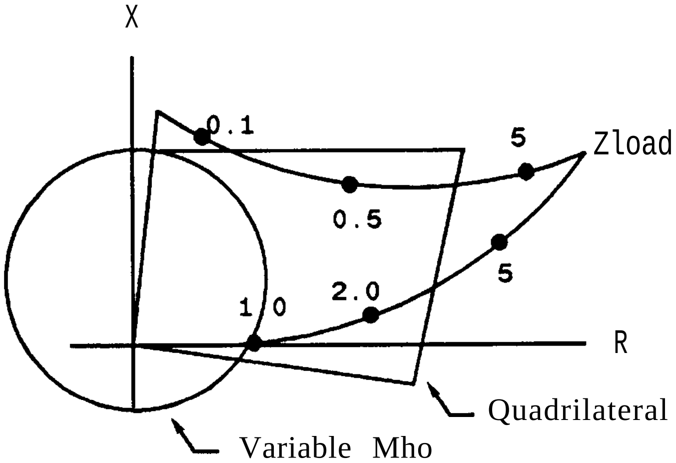
a. Single-ended System b. Double-ended System

Figure 12 - Effect of Infeed on Fault Resistance

far as ground faults are concerned, the resistive component of the fault will appear to be larger to a ground distance function than it actually is. The effect is such that the resistance will appear to be largest to the function at the location with the smallest contribution of fault current.

Because of the magnification of the ground fault resistance and the shift in phase caused by load flow, the performance of some types of ground distance functions could be severely affected. For example, Figure 13 shows that a quadrilateral characteristic has a significant tendency to overreach as opposed to a variable mho of the type used in the TLS system (and in other General Electric ground mho distance functions).

If resistance coverage greater than that offered by the variable mho is required, the ground distance functions in the TLS system can be operated in the negative and zero sequence reactance mode. These reactance functions have an adaptive characteristic that adjusts to



●- Fault resistance in per unit of Zload

Figure 13 - Variable Mho versus Quadrilateral Characteristic

load flow, thus preventing the overreaching/underreaching tendencies displayed by the quadrilateral functions shown in Figure 13.

The performance of a ground distance function may be affected by ground fault resistance regardless of line length because the resistance can be significant or appear to be significant, because of magnification. On the other hand, the effects of fault resistance on a phase distance function will in many cases be innocuous. For example, consider the system shown in Figure 14.

In this system, the first zone functions are set to reach 90 percent of the line impedance. For low to moderately low source to line impedance ratios (Figure 14a), the arc resistance is small compared to the line impedance, thus the possibility of overreaching is virtually non-existent (even with load flow). On the other hand, for very high source to line impedance ratios, the possibility of overreaching is increased (Figure 14b). Another problem exists in that the function may not operate for any internal faults because the arc resistance may fall outside of the characteristic.

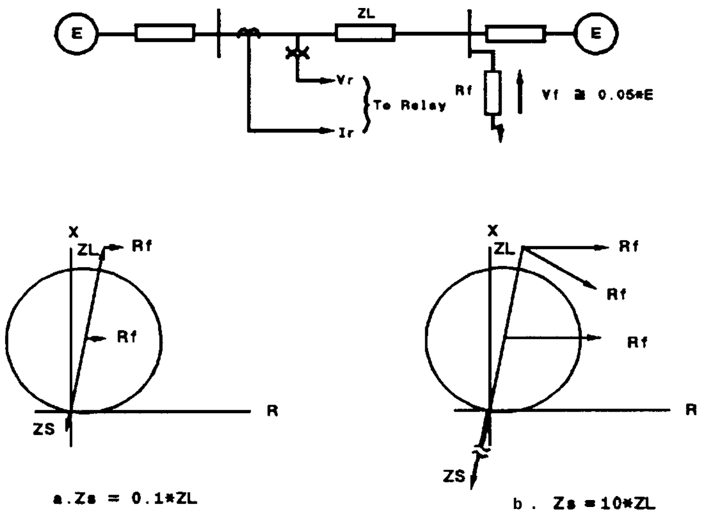
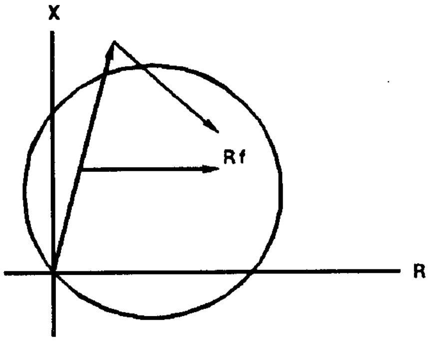


Figure 14 - Effects of Arc Resistance

It is possible to provide an increase in the arc resistance coverage by phase shifting the function as shown in Figure 15a. Unfortunately, this will further increase the tendency to overreach (depending on amount and direction of load flow). To overcome this application difficulty, the current supervision (Vpy) in the phase functions combines with the voltage polarizing signal (Vpy) to form the adaptive reactance characteristic shown in Figure 15b. This characteristic has an adaptive quality because of the zero suppression circuitry that is used in the current supervision signal. At low levels of current, zero suppression will be very effective in reducing the width of the



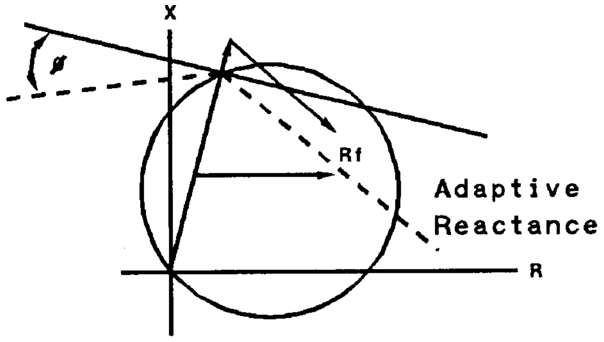


Figure 15 - Effect of Phase Shift

blocks applied to the comparator, and the angle ϕ will be quite large. On the other hand, the blocks will increase in width as the signal level is increased (heavier fault current) and the angle ϕ will reduce accordingly. Thus, to provide a secure application for the situation depicted in Figure 14b (ZS/ZL very large), the zero suppression level should be set on the basis of maximum source impedance (weakest source). With this setting, the function will not overreach for external faults with arc resistance. As the source gets stronger, the current level, and hence the current polarizing signal, will increase and the reactance characteristic will open up to provide increased coverage. Note that the fault resistance will reduce in magnitude as the source impedance decreases, thus the security will not be jeopardized. If the special conditions shown in Figure 14 can never be realized on the line to be protected, the zero suppression level in the current supervision signal should be set to minimum. Arc resistance and load flow for certain system conditions may also introduce another problem for phase mho distance functions. The steady-state security may be jeopardized for a three phase fault directly behind the function, but the function will be quite secure dynamically. Please note that this situation arises only under certain specific conditions. To increase the security, it is proposed that the zero suppression level in the voltage polarizing circuit (Vpx) be set at the five percent level. With this setting, the steady-state polarizing voltage (which is equal to the arc drop) will not exceed the zero suppression level, thus the function cannot operate. It is also possible to increase the security by phase shifting the voltage polarizing signal in the leading direction, by increasing the characteristic timer pickup setting (make the characteristic lenticular), by using forward offset or by adding blocking functions to the scheme.

Series Compensated Lines

The TLS1B system can be applied on lines with series compensation or on lines adjacent to compensated lines. This is made possible through a judicious choice of:

1. design of the distance functions, and
2. the settings used on the functions.

One of the basic problems that can occur on a compensated line is that the voltage at the relay can be reversed from the normal position because of the series capacitor. consider the situation shown in Figure 16.

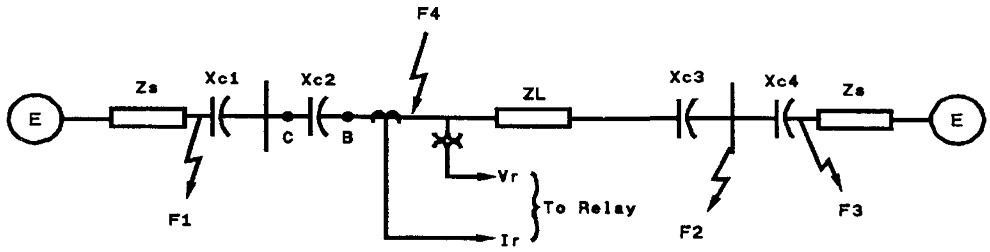


Figure 16 - Typical Series Compensated System

For a fault at F1, the voltage applied to a relay with its potential source located on the line side of capacitor C2 will reverse if the protective gaps do not operate to remove the capacitors from service. The effect of the reversal on a distance function that uses this voltage for polarization is to cause the fault to appear to be internal to the line rather than external as it actually is (on a steady-state basis). If the function has its potential source on the bus side of C2 (location C), an internal fault at F4 will appear as an external fault (steady-state). If the function has a memory circuit in the voltage polarizing signal, it will perform correctly on a dynamic basis regardless of the location of the potential source; i.e., the voltage will not reverse immediately because of the memory action.

The distance functions in the TLS system use positive sequence voltage as the polarizing quantity and are provided with memory circuits. The positive sequence voltage will reverse for three phase faults, but on many systems it will be less likely to reverse for unbalanced faults. Therefore, the function must be relied on to operate dynamically for three phase faults, but it will respond correctly on a dynamic basis, and in many cases, on a steady-state basis for unbalanced faults. Thus, the distance functions in the TLS system will respond correctly to initiate high speed tripping (direct or pilot) regardless of the fault type or fault location relative to the series capacitor and potential source location.

Although the TLS distance functions with their potential source located at B in Figure 16 will provide a correct dynamic response for a fault at Fl, this response may not be long enough to prevent tripping in the event of a breaker failure, or inordinately long breaker times in the adjacent line sections. To overcome this limitation, the blocking functions must be used in all applications involving series capacitors. The blocking functions will operate correctly dynamically, and possibly steady-state, to establish a blocking condition; and they are provided with adjustment in the dropout time to allow their output to last long enough to allow fault clearing by the breakers in the adjacent line sections.

Because the capacitive reactance of the series capacitor cancels the inductive reactance of the line, zone 1 functions cannot be set to protect 90 percent of the line when the capacitors are located in front of the relay location - either in the line itself or in adjacent line sections. It is also recommended that zone 1 functions not be set to reach 90 percent of the compensated line impedance; i.e., [0.9(ZL - XC)]. This is so because of the low frequency transients that are introduced by the series capacitors which can cause a zone 1 function to overreach significantly. The zone 1 functions in the TLS system can be used to initiate direct tripping on series compensated lines, but they must be operated in the B filter/level detector mode. When applied in this way, the level detector can be set on the basis of the gap flashing level when protective gaps are used around the capacitors: or if zinc oxide protectors are used, the level detector setting can be based on the peak voltage that can be tolerated across the zinc oxide before the capacitor bank is shorted. When set in this way, the zone 1 functions cannot operate for faults beyond the remote line terminal, but will operate for heavy faults close to the relay location. If more than one set of capacitors are located in front of the relay, it may be necessary to set the level detector on the combined gap flashing level. If it can be shown that the gaps on a bank in an adjacent line section will always operate to remove that bank from service, then the level detector setting can be based on the gap flashing level on the bank(s) in the line. As an example, consider a fault at F3 in Figure 16. For this fault, infeed at the bus remote from the relay may be sufficient to assure that capacitor bank C4 will always be removed from service. In that case, the gap flashing level of the capacitors located in the line itself (C3 in this example) need only be considered in determining the level detector setting in the zone 1 functions at location B. Note that the zone 1 functions act as hybrid overcurrent/distance functions when applied in this manner and will suffer some pullback in reach. They will, however, provide high speed direct tripping for severe faults close to the function without risk of overreaching for external faults.

If the series capacitors are all located behind the relay (Cl and C2 in Figure 16), the zone 1 functions can be applied as a variable mho function, but the reach setting must be reduced by another ten percent below the setting normally used on uncompensated lines; i.e., 80 percent versus 90 percent.

It is not necessary to make any special settings in the overreaching functions when applied on series compensated lines, but some modifications will be required in the settings of the blocking functions.

First, a 20 degree phase shift must be introduced to the polarizing signal in the MB functions. This phase shift was determined empirically and is used to facilitate coordination with the tripping functions in the presence of the transients introduced by the series capacitors.

When series capacitors are located between the potential sources used to supply the tripping and blocking functions at each end of the line, the impedance seen by the tripping functions for a fault beyond the remote terminal may be reduced because of the capacitors, but the impedance seen by the blocking functions will not. For this reason, the reach of the blocking functions will have to be increased to insure that they will operate for all faults that the remote tripping functions can see.

The negative sequence blocking function uses negative sequence voltage and current to form a directional characteristic via an amplitude comparator. The following quantities are used:

VOP = V2 + KI2ZR2

VREST = 12ZR2

The function operates when the magnitude of the operating quantity is greater than the magnitude of the restraining quantity. It is possible for the negative sequence voltage to be reversed from normal for some system conditions. For example, V2 will be reversed from the normal position when the sum of the capacitive reactance of Cl and C2 is greater than the negative sequence source impedance (ZS) behind the capacitors (see Figure 15). The effect of this reversal would cause the function to operate for internal faults were it not for the compensation factor (K) in the operate signal. Therefore the compensation factor, K, must be set differently when the line, or an adjacent line is compensated. The exact setting to be made will be a function of the system parameters.

Single Pole Tripping

The TLS system can be used to initiate single pole tripping when such operation is required. Only a few modifications are required in the settings. One problem arises because the phase distance functions can operate for some single line to ground faults. If this were allowed to happen, a three pole trip would be initiated when a single pole trip is really required. To prevent this from happening the following is done:

1. The first zone phase functions have zero sequence overcurrent restraint built in. This restraint is such that the function will be prevented from operating for single line to ground faults, but the effect will be minimized on double line to ground faults. This restraint must be switched in when single pole tripping is implemented.

2. The logic is set up so that the ground distance overreaching functions take priority over the phase distance overreaching functions during single line to ground faults. Thus, the phase distance functions will be prevented from initiating a three pole trip. No special settings are required to implement this feature.

The first zone ground distance functions are provided with zero sequence current supervision. On systems using three pole tripping this supervision is set at the minimum level to provide the most sensitive protection. When single pole tripping is used, the setting for this supervision should be based on the minimum zero sequence current for a fault at the end of the line remote from the function. This setting is proposed to prevent overreaching by the first zone ground distance functions in the unlikely event that a phase to phase fault were to occur on an adjacent line at the same time that a pole was open (during a single pole trip) in the line being protected by the zone 1 functions.

It was noted earlier that the ground distance functions use signals derived from the negative and zero sequence current. These two signals form an excellent phase selector in addition to combining with the operating signal to form the negative and zero sequence reactance characteristics described earlier. This type of phase selection assures that the ground distance function associated with the faulted phase only will operate during single line to ground faults. Provisions are included for removing these inputs, so it must be assured that these signals are in when single pole tripping is required.

SCHEME AND CHANNEL CONSIDERATIONS

The TLS system has a common logic module that allows any of the following modes of operation:

1. Stepped distance scheme
2. Zone acceleration
3. Directional comparison blocking scheme
4. Permissive tripping scheme
    a. Overreaching
    b. Underreaching
5. Hybrid scheme
6. Stepped Distance Protection

Stepped distance protection can be obtained in two ways:

1. Three independent zones if three zones of protection are required.
2. Two independent zones when only two zones of protection are required.

The second method is provided with the means to extend the reach of the first zone function to second zone reach following a time delay that is started by the operation of the overreaching functions. Therefore, three zones of protection can be provided via two zones of equipment. Whether or not second or third zone timing is to be implemented is up to the user. When second zone timing is to be used, it is proposed that the switched first zone method be used to implement it, rather than using the overreaching functions as the second zone function. In this way, it may be possible to set the overreaching functions longer than a normal second zone reach and so optimize the operating time as described earlier. The normal second zone reach can then be obtained with the switched zone 1 function.

It is also possible to extend the reach of the zone 1 function by external means via a contact converter provided in the system. The input to the contact converter can come from a channel trip signal thus allowing the system to be applied in a zone acceleration scheme.

This type of scheme is typically applied when overreaching functions are not available for use.

PILOT PROTECTION

The remainder of this discussion on schemes and channels pertains to the tripping, blocking and hybrid type directional comparison schemes.

In earlier days of directional comparison relaying, most schemes used with power line carrier (PLC) were blocking schemes with an OFF-ON channel, and most schemes used over microwave (MW) were tripping schemes with a frequency shift (FSK) channel. With only these two choices, tripping or blocking was sufficient to describe the complete protective scheme.

The introduction of frequency shift channels on PLC, with the unblocking mode of operation, made it possible to provide either a tripping or a blocking scheme over PLC or MW, depending on which frequency (trip or guard) is transmitted in standby. In addition a third relay scheme, called a "hybrid" scheme was developed, which offers some of the advantages of a blocking scheme (trip at one end with weak infeed at the other) but operates basically as a tripping scheme.

In the tabulation of relay schemes and pilot channels given below, the following definitions are used:

Tripping Scheme - requires operation of the local trip functions and receipt of a trip signal from the remote terminals before tripping will be initiated. Scheme contains tripping functions only.

Blocking Scheme - requires operation of the local trip function and the absence of a blocking signal from the remote terminals before tripping will be initiated. Scheme contains both blocking and tripping functions.

Hybrid Scheme - requires operation of local trip function and receipt of a trip signal from remote terminals before tripping will be initiated, but trip signal may be "repeated" from remote terminal if a blocking function has not operated at that terminal. Scheme requires both tripping and blocking functions.

The various combinations of relay schemes and pilot channels are described below:

1. Tripping scheme, FSK tripping channel. Permissive overreaching transfer trip (POTT), transmits the guard frequency in standby condition, and the relay trip functions key the channel to trip frequency. Tripping is blocked on loss of channel. Receipt of trip frequency gives trip permission to local relay.

2. Tripping scheme, FSK unblocking channel. Permissive overreaching transfer trip, transmits guard frequency in standby condition; relay trip functions key the channel to trip frequency and permit trip for short duration if the signal is

attenuated by a fault, then block tripping. Receipt of an unblock signal gives trip permission to local relay (note that an unblock signal can be the receipt of the trip signal from the remote terminal or the loss of signal (LOS) output from the local receiver).

3. Blocking scheme, OFF-ON power line carrier. No signal transmitted in standby condition. Relay blocking functions start carrier transmission and relay tripping functions stop carrier transmission. Receiver output blocks tripping by local relay. Tripping functions initiate tripping independently at each terminal in the absence of a blocking signal.

4. Blocking scheme, FSK tripping channel. Transmitter keyed to trip frequency in standby, relay blocking function at one terminal keys transmitter to guard frequency for external fault. Tripping blocked for loss of channel. Receipt of trip frequency gives trip permission to local relay.

5. Blocking scheme, FSK unblocking channel. Transmitter keyed to trip frequency in standby, relay blocking function at one terminal keys transmitter to guard frequency for external fault. Permits tripping for a short duration if the signal is attenuated by a fault. Receipt of unblock signal gives trip permission to local relay.

6. Hybrid scheme, FSK tripping channel. Transmits guard frequency in standby condition. Relay tripping function keys transmitters to trip frequency. In addition, receipt of a trip frequency plus no blocking function output will key the transmitter for short duration to "repeat" trip signal back to transmitter location. Tripping is blocked for the loss of channel. Receipt of trip frequency gives trip permission to local relay.

7. Hybrid scheme, FSK unblocking channel. Transmits guard frequency in standby condition. Relay tripping function keys transmitter to trip frequency. In addition, receipt of a trip frequency, plus no local blocking function output, will key the transmitter for short duration to "repeat" the trip signal back to the transmitter location. Permits tripping for a short duration if the signal is attenuated by a fault. Receipt of an unblock signal gives trip permission to the local relay.

The following application guidelines should be considered when selecting a relaying scheme and a channel.

1. The blocking scheme with OFF-ON carrier will trip the local breaker for any internal fault whether or not the remote tripping function operates and is therefore suitable for applications with a weak infeed terminal. The channel is not continuously monitored, and is therefore subject to overtripping if the channel fails. A failed channel can go undetected until tested manually or by an automatic checkback scheme.

2. Frequency shift (FSK) tripping channels would normally be used with microwave. FSK unblocking channels would be used with power line carrier to allow tripping on internal faults that cause excessive attenuation in the channel.

3. Where frequency shift channels are used, tripping schemes tend to be more secure because relay tripping functions at both ends of the line must see the fault. They are generally applied where there are good sources of fault current at both ends of the line.

4. Where the source at one end of a line is much weaker than that at the other end, a blocking scheme will permit faster tripping of the heavy infeed end since tripping is not delayed because of slow operation of the tripping function at the other end.

5. For fast tripping of a weak infeed terminal, a hybrid scheme with a weak infeed trip option is preferred.

6. If two FSK channels are used for direct transfer tripping for equipment failure, one of the two channels can be used for the directional comparison relaying. This would be a reason for choosing a tripping or hybrid type scheme rather than a blocking scheme.

SCHEME DESCRIPTION

The TLSlB System includes logic for implementing the following relaying schemes:

1. Stepped distance
2. Permissive transfer tripping
   a. Overreaching
   b. Underreaching
3. Hybrid
4. Blocking

The TLSlB includes the logic and functions for both single pole and three pole tripping with all of the above schemes. By making suitable settings, the TLSlB may be used on lines with series capacitors, or on lines adjacent to series compensated lines.

Permissive Tripping

The permissive tripping scheme is the simplest of the three schemes in that it uses 12 tripping elements (Ml, MG1, MT, MTG). The blocking elements (MB, NB) are used to establish blocking to prevent tripping during fault clearing, during current reversals, or during voltage reversals that can occur on series compensated lines. The essential elements of this scheme are shown in the simplified logic diagram of Figure 17.

The phase and ground directional distance overreaching functions, MT and MTG, reach beyond the remote terminal of the protected line to insure operation for faults anywhere on the protected line. The first zone phase and ground distance functions, Ml and MG1, are typically set for 90 percent of the positive sequence line impedance and trip directly for faults within their set reach. For a fault within the reach of the relay, one or more of the overreaching functions (MT, MTG) will operate. This will apply a signal to AND407 via OR201. AND407 is referred to as the "comparer" and is used to determine if the fault is within the protected line by comparing the output of the local tripping functions with the signal received from the remote terminal. In permissive overreaching transfer trip (POTT) schemes, an output from the overreaching functions will key the associated FSK channel to the trip frequency via 0R205. In permissive underreaching transfer trip (PUTT) schemes, a permissive signal is sent when OR403 produces an output via an input from either of the first zone functions. Link 121A-2 is used to select either a POTT (closed), or a PUTT (opened) scheme. The second input to AND407 is the output of the local receiver. The NOT output to AND407 is not used in this scheme.

For an internal fault, the overreaching functions at both terminals will operate and send a permissive trip signal to the remote terminal. This will apply a trip permission signal to OR405 via AND407, 0R402, TL1, OR403 and AND417. The pickup delay of TL1 is used to provide security against false tripping on external faults due to spurious trip signals from the channel: the 50 millisecond reset time of TL1 prolongs the keying of the transmitter via OR403 and OR205 to insure that the remote terminal will have ample time to trip before the permissive trip signal is removed.

If an internal fault occurs within the reach of a zone 1 function (Ml or MG1), a trip permission signal will occur immediately via 0R402, 0R403, AND417 and OR405. The output from OR403 will also cause a permissive trip signal to be sent via OR205.

During an external fault, the tripping functions at the terminal nearer the fault will not operate because the fault is "behind" them, but the blocking functions will operate, to establish transient blocking. No tripping can occur at that terminal and the transmitter will not be keyed. The tripping functions at the remote end may see the fault, but tripping will not be allowed because there will be no permissive channel input at the comparer (AND407).

Blocking Scheme

The TLS1B relay system is supplied with blocking functions so that it may also be used in a directional comparison blocking scheme with AM (ON-OFF) power line carrier. This scheme includes both tripping and blocking elements and is shown in simplified form in Figure 18.

In this scheme, no carrier is sent in standby or when the trip elements operate. The channel receiver input to the comparer (AND407) is therefore energized in the standby condition via NOT1O1. The operation of the blocking scheme for a fault within the protected zone is similar to that described for the permissive tripping scheme. When one of the overreaching tripping units (MT, MTG) operate, one input to the comparer (AND407) is supplied via OR201; in addition, the output of OR201 energizes the carrier stop output via AND209 and 0R213. The will prevent any auxiliary functions (such as voice or checkback) from sending a blocking carrier signal during an internal fault. All three inputs to the comparer (AND407) will be satisfied since the blocking units will not operate and the blocking carrier will not be received for a fault within the protected zone. The 50 millisecond reset time of TL1 blocks carrier start and prolongs the carrier stop output to insure that the remote terminal will have ample time to trip.

During an external fault, the blocking units at the end nearest the fault are set to operate for any external fault for which the tripping functions at the remote terminal may operate. The tripping functions at the terminal closest to an external fault will not operate because the fault is "behind" them; the blocking units at this terminal will operate causing blocking carrier to be sent to the remote terminal. The tripping functions at the remote end may respond to the fault, but tripping will not be permitted because the carrier input will block the comparer via NOT101 and OR101.

Hybrid Scheme

The hybrid directional comparison scheme operates in a manner similar to the permissive tripping scheme, except that blocking functions are also used as shown in Figure 19. The blocking units allow the channel repeat and weak infeed tripping circuits to be incorporated.

When the hybrid scheme is used on a system with strong sources at each end, it will respond to an internal fault in the same manner as a permissive tripping scheme. On a system where one source is or may be weak, the hybrid scheme offers advantages that cannot be obtained with the permissive trip scheme. Assume a fault on the protected line that can be "seen" by the tripping units (MT, MTG) of the relay at the strong terminal, but not by the tripping units at the weak infeed end. The relays at the strong infeed end will send a permissive trip signal to the relays at the weak infeed end.

In a permissive scheme, the relays at the strong infeed terminal will not be able to trip because they will not receive a permissive trip signal from the relays at the weak infeed terminal. The relays at the weak infeed end will receive a permissive trip signal, but will not be able to trip because the tripping functions will not respond to the fault. In a hybrid scheme, the receipt of a permissive signal at the weak infeed end and the lack of an output from the blocking functions will allow the permissive signal to be repeated back to the relays at the strong infeed terminal via TL12, AND102, AND405 and 0R205. When the repeated signal is received, the relays at the strong infeed terminal will produce a trip output. At the weak infeed terminal, where neither the tripping nor blocking functions have operated, a trip will be initiated via TL16 when the trip signal is received from the remote terminal, provided that the current is less than the **Iϕ-Block** setting and the voltage is less than 0.65 per unit. When an external fault occurs within the reach of the overreaching tripping elements, the blocking functions will operate and block the local trip units, as well as blocking the repeat circuit at 'AND405, preventing the relays at either terminal from tripping.

Single Pole Tripping

If the TLS1B system is applied in a three pole tripping scheme, a TRIP PERMISSION output from OR405 will initiate three pole tripping of the associated circuit breaker(s). In a single pole tripping scheme, however, it is necessary to trip only the faulted phase for single line to ground faults, and to trip all three phases for multi-phase faults. A simplified phase selection circuit is shown in Figures 17, 18, and 19.

The ground distance functions are designed to respond only to single line to ground faults (except for close-in phase to phase to ground faults where both ground units involved in the fault will operate). Therefore, for an internal phase A to ground fault, one input to AND408 will be supplied by the phase MG1 or MTG, while the TRIP PERMISSION signal will supply the other. Only the phase A pole of the circuit breaker will be tripped. Phase A may also be selected by the signal labelled "A open." This signal occurs when the voltage on phase A is less than 0.65 per unit and the current on phase A is less than the setting of the IA Block current detector. These open pole detectors are used to indicate when the associated phase is de-energized, and also to provide phase selection on weak infeed faults, as discussed subsequently.

An output from OR20 will select a three pole trip by applying an input to each of the phase selection circuits. The following conditions will apply an input to OR20 to select a three pole trip:

1. Operation of any first zone phase distance function (any Ml).
2. Selection of more than one phase (two out of three logic).
3. Time delayed tripping - Zones 2 and 3 may be selected by the user to trip single pole or three pole. Zone 4, if used, will always trip three pole.
4. Operation of any overreaching phase distance function (any MT), or the combination of an MT function and the receiver output.
5. Receipt of a three pole trip channel.

Option links are available in the logic modules to select the combination of items 4 and 5 which are best suited for the application.

Intercircuit Fault Protection

The protection of double circuit lines presents an interesting problem when single pole tripping is required. Consider, for example, the system shown in Figure 20. For the fault condition shown, the fault will appear as a BCG fault to the relays on both lines at station A. At station B, the fault will appear as a BG fault to the relays on line 1 and as a CG fault to the relays on line 2. Note that as the fault location moves towards the center of the line, the fault will appear as a single line to ground fault to the relays at both stations. If suitable precautions are not taken, single pole tripping will be initiated on both lines at station B, while three pole tripping will be initiated on both lines at station A.

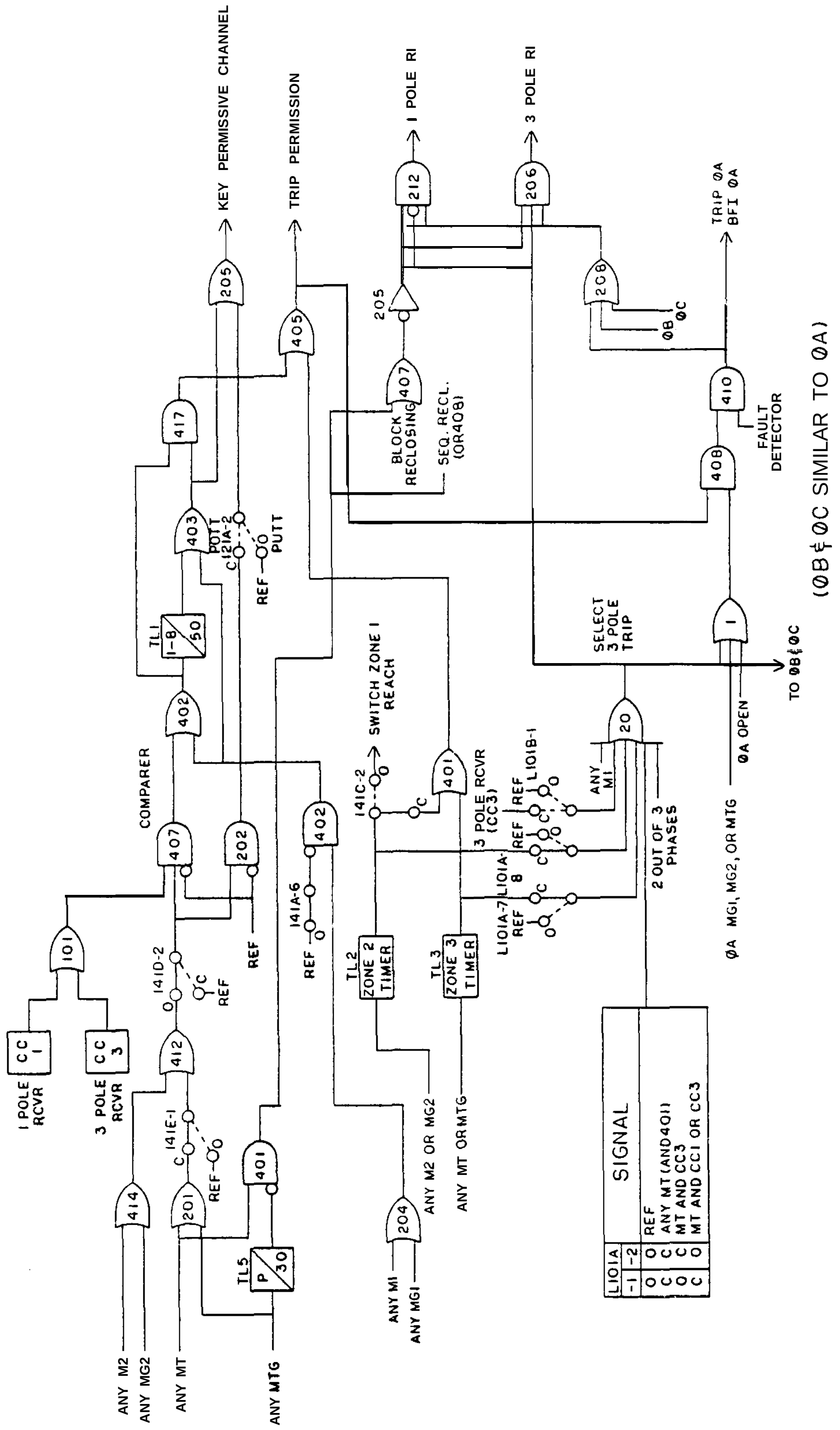


Figure 17 (0179C7544 Sh.1) Permissive Overreaching Transferred Trip Scheme

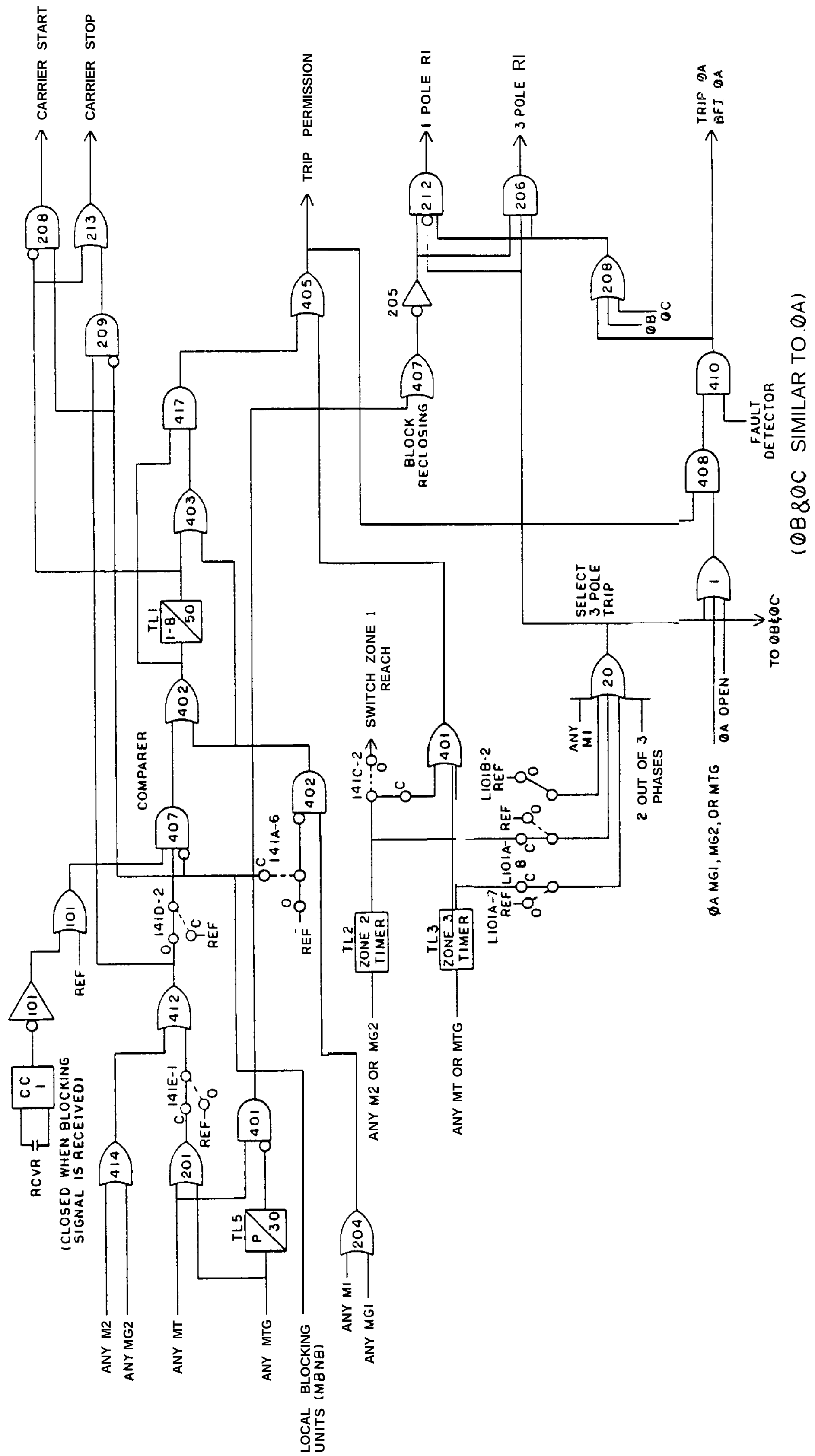


Figure 18 (0179C7544 Sh.2) Blocking Directional Comparison Scheme

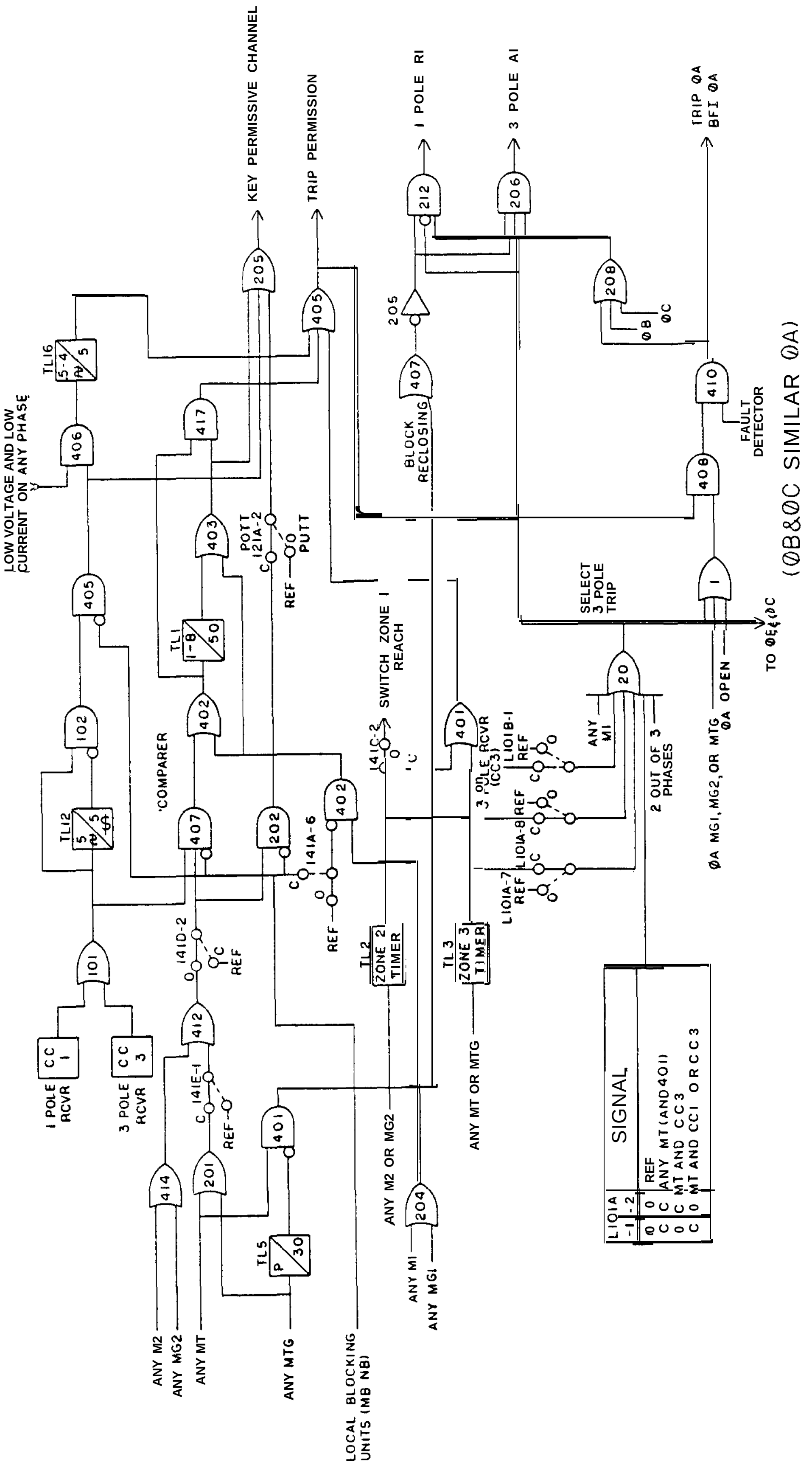


Figure 19. (0179C7544 Sh.3) Hybrid Directional Comparison Scheme

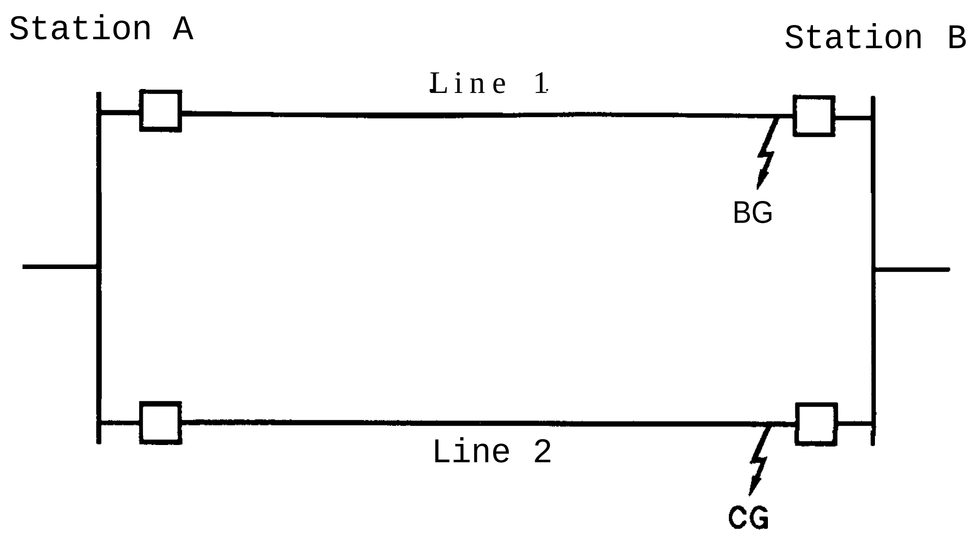


Figure 20 - Double-circuit Transmission Line

The distance functions in the TLSlB relay system are designed such that only the BC phase units will operate at station A, while at station B, only the B phase ground unit will operate on line 1 and only the C phase ground unit on line 2. However, this feature by itself does not solve the problem.

A complete solution involves the use of multiple communications channels. The first solution requires two communication channels. The two channel solution provides correct single pole clearing, as described below, but involves sequential tripping of the breaker remote from the fault.

The two communications channels are used as shown in simplified form in Figure 21. Briefly, the following will occur for the fault condition shown in Figure 20. At station A, the phase BC MT functions will operate and send a three pole trip signal to station B via OR8 and AND205. At station B, the phase B MTG will operate in the protection associated with line 1 and the phase C MTG will operate in line 2. They will send single pole trip signals to the relays at station A via OR206 and AND204. A permissive trip signal will be applied to the comparer via OR101 at both stations. Single pole tripping of the faulted phases will be initiated at station B. No tripping will be initiated at station A at this time, because there has been no phase selection. The MT units are permitted to select a three pole trip only if a three pole trip signal is being received from station B (AND21). As soon as the fault is cleared at station B, the phase BC units at station A will reset and the proper ground units will operate and initiate single pole tripping.

The permissive trip signal keying from station B will be extended beyond the time the breaker clears by TL1 (trip integrator).

A second solution which provides high speed clearing at both terminals, requires four information channels. The channel interface circuits are shown in simplified form in Figure 22. For the fault

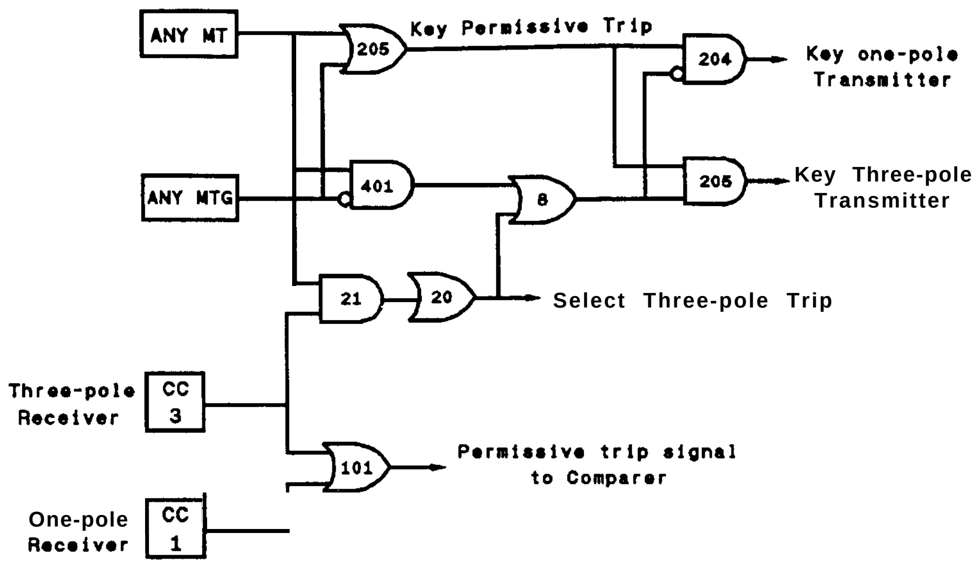


Figure 21 - Channel Keying/Phase Selection for Intercircuit Fault
Two Channel System

condition shown in Figure 20, the phase BC MT will operate at station A and send a three pole trip signal (F4) to station B via OR8 and AND205. At station B, the phase B MTG will operate in the protection associated with line 1, and the phase C MTG will operate in line 2. They will each send a phase identified single pole trip signal to the relays at station A via OR205, AND204 and the TX- relay associated with the faulted phase.

The relays at station B will receive a permissive three pole trip signal (F4) which will energize the comparer via CC3 and OR101. Single pole tripping of the faulted phase will be initiated at station B. At station A, the protection associated with line 1 will receive a phase B permissive single pole trip signal (F2). This signal will energize the comparer via CC1 and OR101; it will also provide phase selection via CC12 and 0R2. This will result in single pole tripping of phase B on line 1 and in a similar manner, phase C on line 2. Note that the MT units are only allowed to select a three pole trip if a permissive three pole trip signal is received, indicating that the relays at both terminals are seeing an interphase fault. As noted earlier, the use of four channels results in high speed clearing at both terminals and does not require sequential tripping of the terminal remote from the fault.

DESIGN FEATURES

Packaging

The TLS system is contained in a modular design package 8 rack units (14 inches) high. The printed circuit boards, transformers, transactors and output relays are contained in pluggable modules. The case includes two 14-point test/disconnect plugs. A single regulated DC-DC power supply module provides the DC supply voltages to both cases. The modular design offers the advantages of reduced size, reduced cost, and ease of installation.

Settings

All of the TLS settings and adjustments are digital and are made using rotary switches, miniature toggle switches (DIP) or printed circuit board-mounted links. The increments used in these settings have been chosen to provide good resolution, thus eliminating the need for vernier adjustments which would require the use of potentiometers. Many adjustments, such as the characteristic angle, the reach and some overcurrent levels are conveniently located on the front panel of the modules. Switches are provided in the logic modules to program the system for various schemes and optional features which are available in the system.

Circuitry

The TLS system includes innovative circuitry which incorporates proven state of the art electronics into traditional relaying functions. The TLS system, like other General Electric Co. relays, uses only hermetically sealed and burned-in semiconductors. The TLS system may be used in an environment where the ambient temperature is between minus 20 degrees and plus 65 degrees Centigrade. The following are examples of the new circuit techniques used in the TLS design.

Timing Circuits

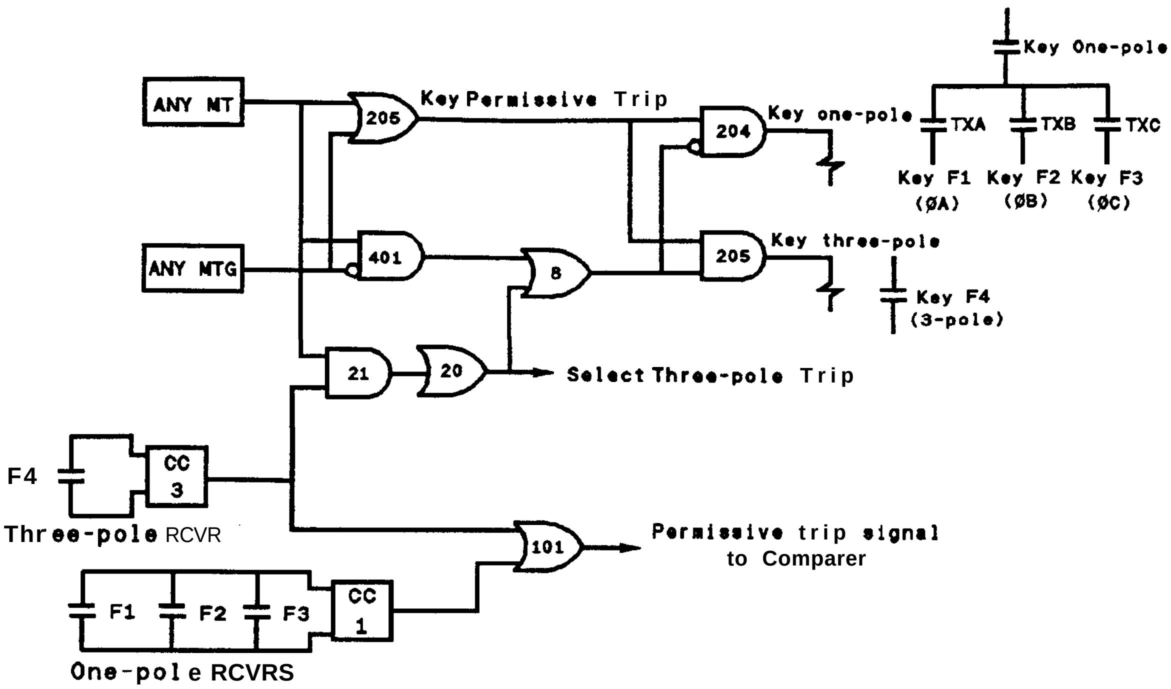
The measuring unit characteristic timers and a majority of the logic timers are digital; that is, the time is established by counting a series of reference or clock pulses. These pulses are provided by a highly stable, continuously running crystal oscillator. A second oscillator, of a different design, is included as backup to the primary crystal oscillator. In the event that the frequency of the crystal oscillator goes outside prescribed limits, a monitoring circuit will switch to the backup oscillator and energize an alarm circuit.

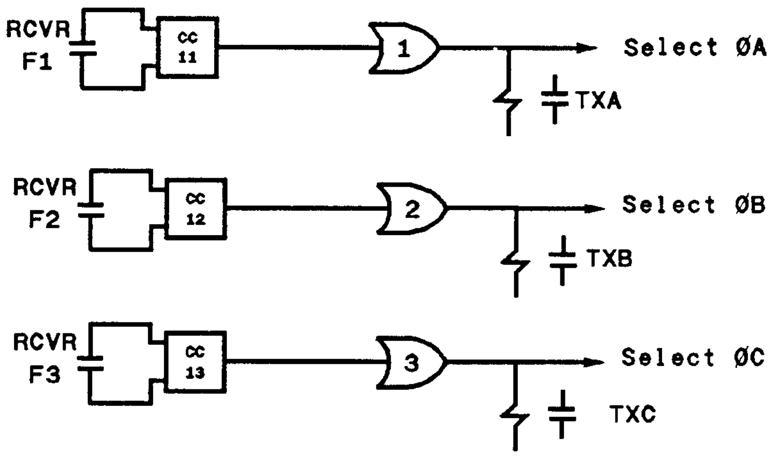
These digital timers are a marked improvement over the resistor-capacitor timers used in previous systems. Performance variations with changes in component values, temperature and age are minimized. The digital timers also provide greater accuracy and ease of setting.

An integrated circuit package was developed to provide all of the special features required by a measuring unit characteristic timer. The'tripping unit characteristic timers are adjustable from 64 to 128 degrees in one degree steps. Because of the special features in this timer chip, it is also used for many of the logic timers.

Operate Circuits

The mho distance functions used in the TLS system are of the phase angle comparator type used in previous designs. There are, however, several significant innovations in the operating circuits of the functions.





Frequency Allocation

F1.....**ØA** Selected
F2.....**ØB** Selected
F3.....**ØC** Selected
F4.....**3** Pole Trip Selected

Figure 22 - Channel Keying/Phase Selection for Intercircuit Faults, Four Channel System

In earlier designs, the reach of the function was adjusted by selecting an appropriate tap on the restraint voltage, and using base reach taps in the current circuits to make major changes in the range of adjustment, i.e., 1 to 10 or 3 to 30 ohms. In the TLS system, on the other hand, voltage taps are used to select ranges of reach adjustment (0.1 to 2.5 vs 1 to 25 for example), and the reach is adjusted by changing the replica impedance in the current circuits. The approach provides improved performance by producing a more uniform energy level in the operating circuit filters over a wide range of reach settings. By varying the IZ quantity, the resolution of the reach is made uniform and improved over that which can be obtained with voltage restraint taps, especially at low tap settings (higher reaches).

Targets

Light emitting diodes (LEDs) are used as trip targets in the TLS system. The LEDs are sealed in until they are reset manually via a front panel reset pushbutton or remotely via an external input to a contact converter. The reset circuit also provides a means of checking the LEDs by momentarily lighting all of the targets when the pushbutton is depressed. The following LED targets are provided:

A	Phase A trip*
B	Phase B trip*
C	Phase C trip*
I	Zone 1 trip
II	Zone 2 trip
III	Zone 3 trip
IV	Zone 4 trip
CT	Channel trip
LP	Line pickup trip
WI	Weak infeed trip
TT	Transfer trip
MOB	Out-of-step blocking**

*Light individually in single pole tripping schemes, whereas all three light in three pole tripping schemes**Does not seal-in.

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