INSTRUCTIONS

GEI-83950

SUPERSEDES GEI-25363

CARRIER-CURRENT PILOT RELAYING

WITH MHO TYPE DISTANCE RELAYS

GENERAL ELECTRIC

CONTENTS

CARRIER-CURRENT PILOT RELAYING WITH MHO-TYPE DISTANCE RELAYS

INTRODUCTION

The load carrying ability of a transmission line depends on the stability limit of the line, beyond which limit power cannot be transmitted and still have the generation behind the two terminals of the line in synchronism. There are two types of stability limits; the steady-state limit, and the transient limit. In reaching the steady-state limit the power transmitted over the line is increased gradually so that the generation is able to take up the increases in load with no tendency to overshoot due to mechanical inertia of moving parts in generator or governing equipment. The transient stability limit can be reached by a disturbance to the system which brings inertia reactions into play.

Continuity of service depends on keeping all parts of a transmission system in operation or at least in an operable condition for a maximum percentage of the time. Conversely, the amount of time a transmission line is out of service for maintenance or due to a short circuit must be held to a minimum.

The longer the transmission system is subjected to the disturbance of a fault, the greater is the possibility of transient instability, and the greater is the damage to the electrical equipment. Thus it is important from both the standpoints of stability and continuity of service that faults be cleared as quickly as possible. It is equally important that the fault be cleared by taking a minimum of the system out of service, or, in other terms, that the protective relay be "selective" to the highest possible degree.

For non-persistent faults, high-speed reclosing is an invaluable aid to both system stability and continuity of service, but this subject deserves more emphasis than can be given here and consequently will only be mentioned briefly.

CARRIER-CURRENT RELAYING

Pilot relaying is characterized by an intercommunication system between two or more terminals of a transmission line, over which information is transferred from terminal to terminal. The information obtained from any one terminal is in itself inadequate for high-speed selectivity, but the total information received from all terminals is sufficient to produce a relaying system of maximum selectivity and speed.

By using a channel of high-frequency current (30 to 200 kilocycles/second) the power conductors themselves can be used to carry efficiently the required relaying information. Coupling capacitors with safe insulation to high voltage can be used to lead to and draw from the power conductors the high-frequency current with low impedance to this current and high impedance to the power frequency current. Parallel resonant circuits called "traps" turned to the carrier frequency confine this high-frequency current to the section of the power line between the relaying terminals without introducing any appreciable impedance to the power line current. These traps prevent the carrier signal from being drained off by an external fault, which would render the carrier current relaying ineffective at the time when it is most needed.

Thus, the use of high-frequency carrier current to convey the necessary relaying information allows the power conductors themselves to be used to effectively transmit this information.

FAULT LOCATION

As described in the subsection "Carrier-Current Relaying" it is necessary for the relays at the terminals of a protected line to compare via the carrier-current channel what each terminal of relays "sees" under fault conditions. It is obviously necessary that any relay which is used to determine in what direction a fault occurs must have a sense of direction, that is, it must be a directional relay. Therefore, directional relays are used at each terminal to determine whether the fault is internal (in the protected section) or external (outside the protected section). When an internal fault occurs, the line should be de-energized completely and quickly by tripping the line circuit breakers at each terminal. When the fault is external the circuit breakers should not be tripped immediately but should allow time for the breakers on the faulted external line section to trip.

Considering the directional relays at each end of the protected section, let us examine their basic operation in a carrier-current relaying scheme. Please refer to Fig. 1.

Fig. 1 represents three adjacent transmission line sections, with circuit breakers A, B, C, D, E, and F, and faults shown in locations X, Y, and Z. Let us consider the section between the breakers C and D as the section to be protected by carrier-current relays. The directional relays at breaker C operate only for faults to the right of breaker C, and directional relays at breaker D operate only for faults to the left of breaker D. This means that the only faults that can operate both the directional relays at C and D are those faults that occur between C and D (internal faults). Faults such as Y and Z will operate only one of the directional relays, e.g., fault Y operates only the directional relays at D; fault Z operates only the directional relays at C.

Thus, we have a distinguishing characteristic between internal and external faults. Internal faults cause the directional relays at both terminal C and D to operate, external faults operate the directional relays at only one terminal. It is the function of the carrier channel to indicate instantaneously to both terminals whether or not the directional relays at both terminals C and D have operated.

METHOD OF COMMUNICATION

Briefly, if the fault is external, carrier-current is transmitted for the duration of the fault from one terminal to block tripping at each terminal. If the fault is internal, carrier-current transmission is stopped instantaneously at both terminals, and both breakers are tripped. Also, if there is no fault carrier-current is not transmitted from either terminal. Speaking in terms of the directional units, the directional unit causes carrier-current transmission from the local transmitter to stop whenever the directional unit operates.

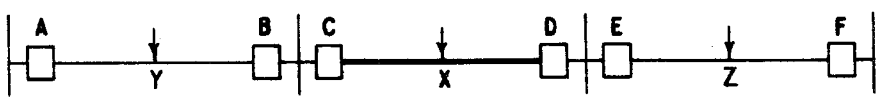


Fig. 1 Typical Transmission Line (6400721 Sh.1-2)

If carrier-current transmission is off under normal unfaulted conditions, and the directional units operate to stop carrier-current transmission, it is obvious that something is needed to start transmission. This function is performed by additional elements which must be sensitive to faults and very fast, but need not be directional. It is vital to start carrier and block tripping for every external fault. Therefore, the carrier-starting fault detectors must operate faster and be more sensitive than the directional units. More will be said about this co-ordination later.

Let us summarize the basic facts of carrier-current pilot relaying:

1. The transmission of carrier-current from any terminal prevents tripping of each terminal of the protected section.
2. Carrier-current is transmitted for external faults by the operation of fault detectors.
3. Carrier-current transmission is stopped at each terminal for internal faults by the operation of the directional relays at each terminal, thereby allowing tripping at each terminal.
4. The carrier-current transmission is off under normal, unfaulted conditions.

Referring back to Fig. 1 let us examine the relay operations for an internal and an external fault noting the approximate accumulative times in the sequence in cycles on a 60 cycle per second basis.

For an internal fault:

1. (0 cycles) Fault occurs at X.
2. (1/2 cycle) Fault detectors at C and D operate, starting carrier current at C and D.
3. (1 cycle) Directional relays at C and D operate, stopping carrier current at C and D.
4. (2 cycles) Trip coils of breakers at C and D are energized.
5. (5 to 10 cycles) Breakers at C and D open, de-energizing faulted line section.

For an external fault:

1. (0 cycles) Fault occurs at Y.
2. (1/2 cycle) Fault detectors at C and D operate, starting carrier current at C and D.
3. (1 cycle) Directional Relay at D operates, stopping carrier current at D. Carrier current at C is not stopped, it is received at both C and D and tripping is prevented at both C and D.
4. (Some time after 5 cycles) Breakers A and B open, due to the operation of the relays at A and B, de-energizing faulted line section.

DESCRIPTION

The directional units of the standard carrier terminal are of high-speed induction cylinder construction. The phase units are provided with voltage restraint to enable them to distinguish between fault conditions and normal operating conditions. For reasons which are of no particular interest here, the resulting unit is called a mho unit.

The following paragraphs will discuss the functions of all the elements of the standard carrier-relaying terminal.

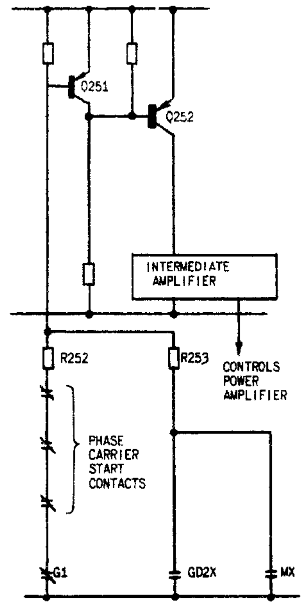


Fig. 2 Carrier Starting Control of the CS27 (0165A6077 Sh.2-0)

CARRIER-CURRENT FUNCTION

STARTING CARRIER-CURRENT TRANSMITTER

In the Type CS-27 General Electric relaying transmitters, transmission is controlled by means of the voltage bias on the base of a transistor in the keying unit. When this base has a negative bias the intermediate amplifier is de-energized and therefore it supplies no input to the power amplifier, and there is no carrier signal transmitted. When this base is biased positively, the transistor switches the intermediate amplifier on, and it supplies a signal to the power amplifier, so a carrier signal is sent out on the power transmission line. The connections are arranged so that the carrier-starting contacts, which are closed under normal conditions, maintain a negative bias on the base of the carrier starting transistor. Fig. 2 shows these connections for the phase carrier starting relays.

In the symbols for transistors Q251 and Q252, the electrode with the arrow is the emitter, and the direction of the arrow shows the forward direction of current flow from emitter to base. The base connection is shown at the left of the transistor in this particular diagram, and the remaining connection, at the lower right, is the collector. Since the current flows from positive emitter to negative base, these are PNP transistors. When the base is biased negatively, the emitter-base circuit conducts, and this causes the emitter-collector circuit also to conduct, and in this condition the transistor acts as a closed switch. When the base is positively biased, no current flows from the emitter to the base, and therefore no current flows from the emitter to the collector, and the transistor acts like an open switch. Tracing these relations in Fig. 2, when the carrier starting contacts are closed, the base of Q251 is biased negatively so Q251 is on. This biases the base of Q252 positively, so Q252 is off, and there is no signal past that point.

Conversely, when any of the carrier-start contacts are open, the base of Q251 is at its most positive potential and Q251 is off, so that the base of Q252 is negatively biased and Q252 is on. This supplies power to the intermediate amplifier, and therefore a carrier signal is sent out on the power transmission line.

In any of these carrier terminals, MX is controlled by a mho unit with a setting long enough to respond to any internal fault on the protected section. In the GXC17, this is the zone-3 unit (M) which gives the relay its directional properties. In the other forms, MX is controlled by the zone-2 mho unit (M2), or in some cases by a mho unit which is not used for any other purpose.

The characteristics of the carrier-starting units are shown referred to an impedance diagram in Fig. 3. This diagram represents the impedance values for one phase of a transmission line as determined from the ratio of the phase-to-phase voltage divided by the vector difference of the currents in the two corresponding conductors. In both cases the units operate for conditions inside the circle.

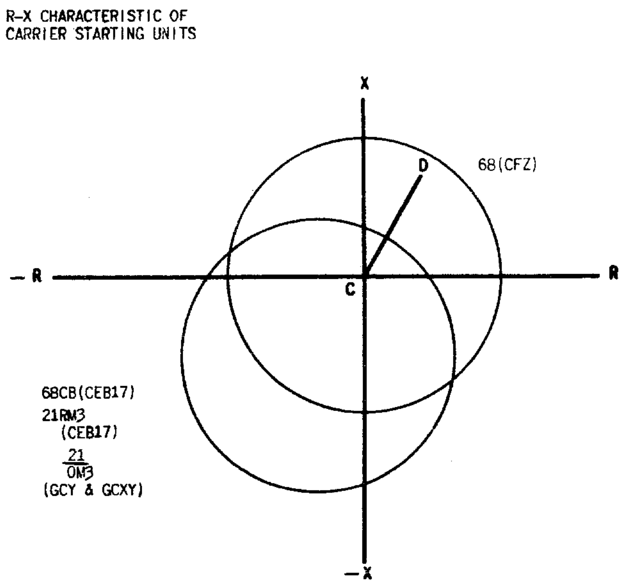


Fig. 3 Carrier Starting Relay Characteristics (6400721 Sh.3-2)

In Fig. 3 the characteristic of the impedance unit 68 (CFZ) is shown as a circle with its center at the origin.

In the diagram the line CD represents the conditions for various faults on the transmission line between C and D. It will be noticed that with carrier-starting relays having offset-mho characteristics, faults may occur near D for which carrier will not be started at C. This makes no difference in the operation since the directional relays at C would immediately stop the carrier signal for a fault within the protected section.

It should be emphasized, however, that in relaying terminals using carrier-starting relays having offset-mho characteristics, the carrier starting unit must be used reversed and offset as the characteristic of Fig. 3 indicates. The unit must be reversed in order to insure starting carrier for external faults which would be in the tripping direction for the remote terminal. The unit must be offset so as to maintain the carrier signal for a zero-voltage external fault behind the terminal after the memory action of the unit has expired.

Since the units described above will not generally operate on single line-to-ground faults it is necessary to provide an additional unit to start carrier for such faults. This unit is called G1 and is simply a low-set instantantaneous overcurrent unit. In other words it operates to start carrier whenever ground fault current is flowing at the particular terminal under consideration. This requires a normally closed contact in series with the carrier starting contacts of the phase relays as shown in Fig. 2.

CONTACT CO-ORDINATION

Referring to the elementary diagram, it will be seen that the CLPG relay includes an auxiliary relay GD1X whose contacts are also in the carrier control circuits. This is a telephone-type relay with a 2 cycle time delay pickup and a 5 cycle time delay dropout. The purpose of this relay is to prevent accidental tripping, by continuing to send a carrier signal when the clearing of an external ground fault removes or reverses the fault current in the GD unit, and causes the possibility of the contacts rebounding due to the removal of restraining torque. There is no similar unit for phase faults because the phase relays have a voltage restraint which hold them open after the fault is cleared.

STOPPING CARRIER-CURRENT TRANSMITTER

In order that the carrier-current controlled relays shall trip the circuit breakers for an internal fault, it is necessary to provide a means for stopping the transmitter for such a fault. This is done, as explained previously, by directional units looking into the protected section. The directinal units stop carrier transmission through auxiliaries MX and GD2X which may be considered merely as repeaters for the directional units. These auxiliaries are of the telephone type and stop carrier by re-applying negative potential to the base of transistor Q252 through resistor R253, as shown in Fig. 2. The BCA relay contains these auxiliaries.

To perform the carrier-stopping function, MX is controlled by the mho units of the CEY16A, GCX (the M unit), or GCY (the M2 unit).

The GD2X unit is controlled by two units, GD and G2, connected in the ground carrier trip circuit. The GD unit is connected to pick up for internal faults. The G2 unit is a residual overcurrent unit; this has been found desirable in order to avoid tripping on extraneous currents such as the zero sequence charging current encountered when a parallel line is faulted.

The two sets of units, (M, M2, etc.) and GD, are thus the co-operating fault-locating "observers" mentioned before under "Fault Location". Identical equipment to that described above is, of course, provided at each terminal of the protected line section.

RESERVE SIGNAL TEST

The reserve signal test is made by operating the transmitter at a power level sufficiently reduced to operate the receiver at the other terminal within the linear portion of its output range, and thereby it is possible to get an indication of the attenuation of the carrier current channel. This reduced level of transmitter output is obtained by limiting the input to the intermediate amplifier by means of a "reserve signal" (R.S.) contact of the test switch as shown at the right of Fig. 4. For the present, it is sufficient to assume that power from the positive bus is being supplied to the R.S. rheostat through transistor Q254. Switch S251 in parallel with the R.S. rheostat circuit, is located in the carrier transmitter assembly and is used to turn on the transmitter at full power, for test purposes. The transmitter modulator for the telephone is also supplied through transistor Q254, to -33 volts.

RELAY PREFERENCE

In case of an internal fault, it is necessary to have some means for turning off any signal that may have been started for R.S. test or by S251 or by the modulator for the telephone, so as to provide high-speed tripping rather than permit false blocking by this signal. This feature is provided by resistor R259 and transistors Q253 and Q254. This group of components acts similarly to R252, Q251, and Q252, so that when R259 is connected to the negative supply, transistor Q254 is turned off. Referring to Fig. 4, it will be seen that the carrier-stop contacts control transistors Q251 and Q252 for the relay carrier signal by means of R253, and they also control transistors Q253 and Q254 for the test signal etc. by means of R259. This constitutes relay preference, and it operates instantaneously without the delay of any telephone relay.

CARRIER-CURRENT RECEPTION

The transmitted signal is received in a receiver similar in operation to a home radio, and the output of the receiver is put to work through the medium of a receiver relay. This receiver relay, R, is energized by the output of the receiver and when energized picks up to open "a" contacts in the carrier trip circuit and thus prevents tripping.

CARRIER ALARM

Relay RA is a telephone-type receiver alarm relay connected in series with the pilot coil of the receiver relay. It picks up whenever carrier current is received, to operate a bell and a lamp for test or signalling purposes. Its pickup is higher than that of the R relay so that if a test signal picks up RA the carrier receiver output will be great enough to reliably operate the R relay.

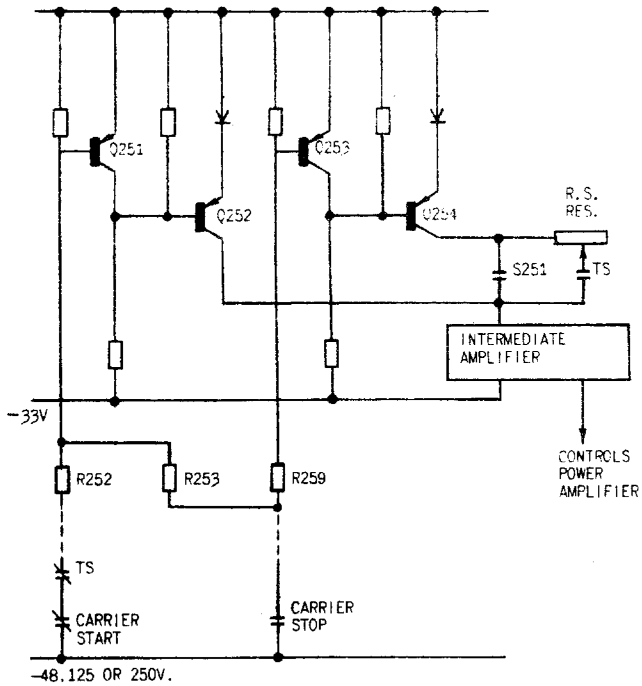


Fig. 4 CS27 Keying Control and Standard Keying Contact Connections (0165A6077 Sh.1-0)

CARRIER TRIP CIRCUITS

The carrier trip circuits are those which energize the trip coil of the circuit breaker if carrier-current is off during the fault, and do not trip the breaker if carrier current is received for the duration of a fault. Other protective relays may trip the same breaker, but tripping by these relays is not primarily dependent on the reception or absence of carrier current.

Fig. 5 shows the carrier trip circuits and associated auxiliary equipment. The phase carrier trip circuits are controlled by mho unit contacts M and by the receiver relay R. Fig. 5 shows how the auxiliaries MX and GD2X are controlled directly by the mho unit and carrier ground relay.

In these carrier-current relay schemes, targets are provided to indicate all possibilities of fault tripping. These target locations and functions are as below:

1. A target in the receiver relay indicates when a carrier trip occurs.

2. A target in the ground relay indicates when ground is involved.

3. A target in the phase relay(s) indicate (s) the operation of a phase relay.

4. In the case of distance relays used also for backup, targets in the RPM timer indicate the time zone involved.

5. Targets in the ground back-up relay indicate a ground back-up trip.

In order to prevent a "race" between the opening of the receiver relay contact R due to the reception of a carrier signal and the closing of the phase or ground fault detecting relay contacts upon the occurrence of an external fault, the contact R of the receiver relay is held in the open position for unfaulted conditions. This precludes the possibility of tripping the breaker through the carrier trip circuit while carrier is being started. This is accomplished by an additional d-c holding coil on the receiver relay. This coil is controlled by the contacts GD2X and MX as shown in Fig. 6.

Thus we have two coils controlling the R relay, one energized from the carrier receiver and the other energized from the d-c control bus. When either one, or both of these coils are energized, the R relay opens the carrier trip circuits shown in Fig. 5. When a fault occurs in the direction of the protected section, the fault detecting relay operates, and the auxiliary unit MX or GD2X opens the contacts shown in Fig. 6 to de-energize the R holding coil. However, the fraction of a cycle (60 cycle basis) required to operate MX or GD2X is sufficient to insure that the receiver relay R does not drop out before carrier current is received to energize the other coil of R, which will keep the R contact open and thus prevent incorrect carrier tripping for an external fault. Of course, if the fault is internal, no carrier current will be received to hold the R relay in the operated position after the holding coil is de-energized and R will drop out, permitting tripping through the circuits of Fig. 5.

BLOCKING AND RECLOSING FUNCTIONS

OUT-OF-STEP BLOCKING DURING POWER SWINGS

These carrier-current relaying schemes recognize out-of-step and power swing conditions by using more sensitive relays which will operate earlier on these conditions, but which will be by-passed under fault conditions. The MB unit in Fig. 7 is an offset mho unit in a Type CEB relay and is connected to operate in the direction of the protected section. This unit is placed in only one phase of the line since it is probable that a power swing or out-of-step condition will appear the same in all phases. The Z units in Fig. 7 used in the GCX scheme are impedance units in a Type CFZ relay and they perform the function of fault detection in addition to out-of-step blocking; consequently, they are present in all three phases.

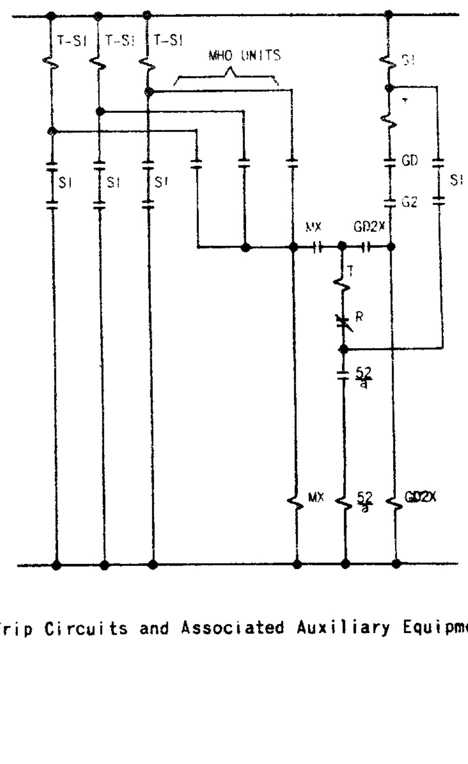


Fig. 5 Carrier Trip Circuits and Associated Auxiliary Equipment (0165A6077 Sh.3-0)

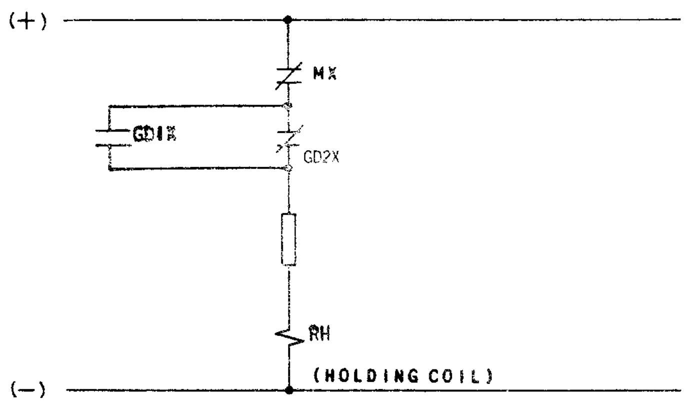


Fig. 6 Holding Control for the Receiver Relay (6400721 Sh.8-3)

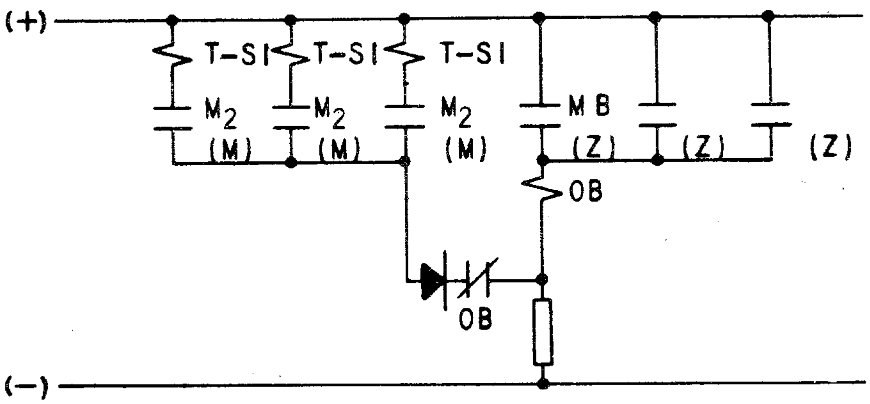


Fig. 7 Out of Step Blocking Control (6400721)Sh.11-3)

The OB element shown in Fig. 7 is a time-delay telephone-type auxiliary relay. It is adjusted for a 4 cycle delay on pickup. This auxiliary is usually used either to prevent a breaker from tripping on an out-of-step or power swing condition or to prevent a breaker reclosing after it has tripped on an out-of-step condition. With relays other than the GCX17 it is more commonly used to prevent the breaker reclosing operation because the mho characteristics are the smallest characteristics available for enclosing the fault area and are thus unlikely to cause tripping on any system disturbance from which the system will normally recover. Even for a complete loss of synchronism, tripping will not occur unless the impedance locus happens to fall within the relay characteristic i.e., in the immediate neighborhood of the protected section.

When an out-of-step condition begins, the apparent system impedance moves along a locus passing through the electrical center of the system at a speed dependent upon the rate of progress of the swing. Fig. 8 shows such a locus on a typical R and X diagram. As the system impedance moves to a point C just inside the MB (or Z) unit characteristic, this more sensitive unit will close its contacts energizing the OB relay. If, within the next four cycles, the system impedance moves to a point D on the locus, just inside the M2 (or M) unit characteristic, this unit will close its contacts shorting out the OB relay coil through the OB "b" contact and tripping the breaker either instantaneously as a carrier trip, or as a time delay trip if a carrier signal is being received from the remote terminal. If on the other hand the system impedance only moves from point C to point E in four cycle time, the OB relay will pick up and block tripping in zone 1, zone 2, and the carrier trip circuits, or prevent reclosing under these conditions. These conditions are therefore recognized as an out-of-step or power swing condition by the speed with which the system impedance moves along its locus.

When a fault occurs the MB (or Z) and M2 (or M, etc.) units operate simultaneously, so that the OB relay coil is bypassed through its own "b" contact by the M2 (or M) contacts before OB can pick up to prevent such shorting. Thus, out-of-step blocking quite correctly does not occur.

INITIATION OF RECLOSING

It is usually desired to provide automatic high-speed reclosing only when a circuit breaker is tripped instantaneously by the carrier or zone 1 units, since otherwise the tripping may be non-simultaneous, in which case reclosing will be unsuccessful. High-speed reclosing is initiated by the trip alarm auxiliary, RI. This device is a telephone relay which is energized from the instantaneous trip bus.

The blocking rectifier in the NAA relay separates RI and the instantaneous trip bus from the trip wire and thus prevents RI from responding to manual or time-delay trip impulses. The parallel capacitor protects the rectifier from overvoltage when RI is interrupted.

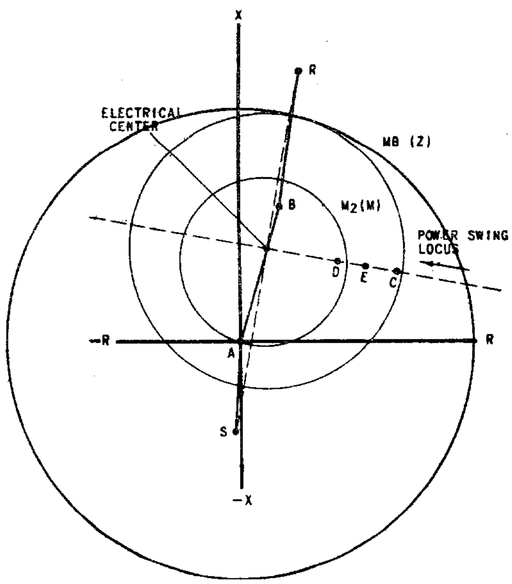


Fig. 8 Out-of-Step Blocking Coordination (6400721 Sh.13-2)

TABLE "A"

TABLE NUMBERS			FUNCTIONS						SETTINGS							
SCHEME	ELEM. DIAG.	TERMS	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
CEY-CEB	7021B99CA	2	x	x					x	x						
		3	x	x					x		x					
2CEY-1CEB	7138B42CA	2	x		x				x			x				
GCY	7021B81CA	3	x			x			x				x			
GCX17	7021B82CA	2	x				x		x					x		
GCXY	7021B83CA	2	x					x	x						x	
		3	x					x	x							x

MANUAL FEATURES

CARRIER TEST SWITCH

The carrier test switch, TS, performs the following functions:

(a) It shunts the reserve signal micro-ammeter except when it is in the REC position to receive a test signal.

(b) It starts the transmitter for testing, SEND.

(c) It inserts the micro-ammeter for measuring a signal from the remote transmitter, REC.

(d) It introduces an attenuating resistor into the transmitter supply so that the receiver output current at the other terminal (s) is made to vary with the received signal voltage. Since the received signal voltage depends on the attenuation over the power conductors, this is often used to detect and roughly measure the amount of sleet on the power conductors.

CARRIER TRIP CUTOFF SWITCH

This switch, designated as CCS, is used to open the carrier trip circuits in case an essential part of the carrier-current relaying equipment is out of service for maintenance or other reasons. Under such conditions protection is provided by the distance relays with their zones of protection, and by the time-delay ground back-up relays.

This switch should be turned to the "OFF" position whenever the carrier-starting relays at another station are out of service for any reason, as otherwise a fault external to the other terminal may cause false tripping of this terminal.

FUNCTIONS AND SETTINGS

Table A lists the tables showing the functions and settings of devices used in the several schemes. Tables I and VII cover the devices common to all the schemes.

It is important to note that protective relay settings depend on system conditions and the circuit to be protected. For this reason, the information supplied in the attached tables can only be qualitative and not quantitive. The user must calculate his own relay settings and these must be applied to the relays by the user before the relays are put into service.

BASIC RULES FOR SETTINGS

In order to insure proper operation of the protective schemes covered by these instructions the following general rules must be followed with regard to relay settings. They are stated here for better understanding.

A. BACK-UP GROUND RELAYS

1. The pickup setting of the high speed units must be high enough to insure that these units do not pick up for any ground fault external to the protected line section.

2. The pickup setting of the time delay units must be low enough to insure positive operation for all single-phase-to-ground faults on the protected line for all practical system operating conditions. Unless local backup is provided at the terminal (s) leading out of the opposite station (s) the setting should be low enough to provide backup for all adjacent line sections in the forward direction, at least sequentially. The time-dial setting must provide for time coordination with similar relays on all adjacent lines in the forward direction.

B. CARRIER GROUND RELAYS

1. Since high-speed carrier stopping and tripping depends on the operation of the directional units of the carrier ground relays, these directional units (GD) at all terminals must pick up for all single-phase-to-ground faults in the protected line section for all practical system operating conditions. Dual polarization provides for maximum sensitivity and should be used where facilities are available.

2. Since high-speed carrier tripping also depends on the operation of the overcurrent units (G2), these units at all terminals must pick up for all single-phase-to-ground faults in the protected line section for all practical system operating conditions.

3. Since proper carrier blocking for external ground faults is necessary for blocking false tripping, the overcurrent units (G1), which start carrier, must be set more sensitive than the overcurrent units (G2) at the remote terminals of the protected line setion. In general, the magnitudes of zero-sequence currents flowing in all three terminals of a three-terminal line for an external ground fault are different. Because of this, the ratio of G1 setting to G2 setting will depend on the number of terminals that the protected line has. This has been reflected in the suggested settings for G1 and G2 in Table VII.

C. CARRIER GROUND RELAYS ON 3-TERMINAL LINES

With an external tie between two terminals of a 3-terminal line as shown in Fig. 9, it is possible to have a considerable magnitude of ground current flowing out of terminal B for an internal fault near terminal C. This will cause blocking of the other terminals, so no tripping can occur until back-up relaying trips the breaker nearest to the fault. Depending on the system configuration and the fault location, the current magnitudes and direction may vary from this situation, all the way to the normal situation of current flowing into the faulted line at all terminals, in four stages as outlined below. The same type of situation can exist on phase faults, but it is a little easier to deal with because the voltage restraint in the distance relays used as phase fault detectors compensates them for changes in source impedance, and therefore their reach changes less than that of the ground relays, with system conditions.

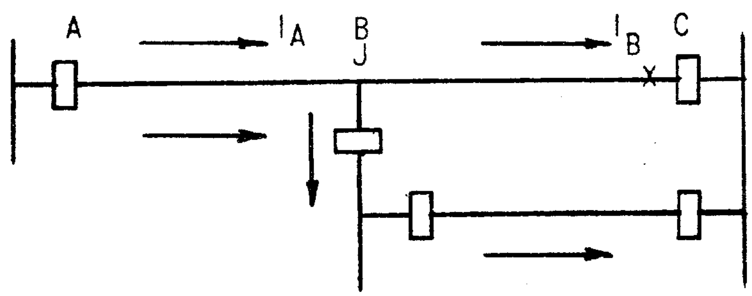


Fig. 9 Three Terminal Line (0165A6077 Sh. 4-0)

1. Out-flowing Current Above G1-Pickup

For this case (as mentioned above) G1 will start carrier at B, thus blocking A and C. The primary relaying cannot operate, so the clearing depends initially on the back-up relaying at C. Since the minimum clearing time at C is about four cycles, and the pickup time of GD1X at B is the pickup time of G1 plus two cycles, GD1X will probably be set up, and therefore the carrier relaying at A and B still cannot respond until the five cycle dropout time of GD1X at B has expired.

This is delayed sequential tripping, and as far as a blocking system of relaying is concerned, there is no remedy for this situation if the setting of G1 is already the highest that can be used with sufficient margin for blocking A in case of an external fault beyond C. (For the margin necessary for this latter situation, see Case 4, below.)

2. Out-flowing or In-flowing Current Below G1 Pickup

Note that for any system configuration where Case 1 can arise, Case 2 will arise instead, if the fault location is further away from C.

For this case, G1 does not operate, so carrier is not started at B, GD1X does not pick up, and tripping at A and C is normal. B will trip as soon as C has cleared.

This is instantaneous sequential tripping, and as far as a blocking system of relaying is concerned, there is no remedy for this situation if the setting of GD is already the lowest that can be obtained.

3. In-flowing Current Above G1 Pickup But Below G2 Pickup

Note that for any system configuration where Case 1 and 2 can arise, Case 3 can arise instead, if the fault location is still further away from C.

For this case, G1 starts carrier at B, thus blocking A and C. As in Case 2, the primary relaying cannot operate, so the clearing depends initially on the back-up relaying at C. However, unlike Case 2, GD picks up, so GD1X does not pick up, and therefore the primary relaying will trip A and B as soon as C trips by back-up relaying.

This is instantaneous sequential tripping of terminals A and B. For the narrow range of ground fault currents, or of ground fault locations, represented in Case 3, it is possible to have an auxiliary relay at B which will respond to the operation of GD and will bypass G1 contact in the carrier starting circuit, thus making the primary relaying again effective at A and C, and eliminating the instantaneous sequential tripping of A. However, terminal B will still have only instantaneous sequential tripping, and this must be taken into account in choosing the dead time of the breakers at A and C in case of instantaneous reclosing. Therefore the only practical advantage obtained by the added auxiliary relay at B is that in the current range between G1 and G2 it keeps the primary protection at A and C effective rather than having to depend on the back-up relaying to trip C. It does not improve the performance for Case 1 or 2, if either of these cases can exist for any fault location on the protected line.

4. In-flowing Current Above G2 Pickup

For this case, operation is normal at all terminals if the proper margin has been taken in choosing the settings. An internal fault will be cleared correctly, and the only concern necessary is the result of an internal fault. Considering Fig. 9, an external fault at the right may draw equal currents out of terminals B and C, but the sum of these currents will flow in through A if there is no ground current supplied from any other line or grounded bank at B. In order to insure blocking at A for a fault which would draw currents just below G1 pickup at B and C, it is necessary to set the pickup of G2 at A for at least 2.5 times the pickup of G1 at B or C, rather than only 1.25 times. Unless fault data are available to prove it unnecessary, the usual meshed system (with external interconnections possible among each pair of terminals) requires a similar 2.5:1 ratio of G2 pickup at any terminal to the G1 pickup at each of the other two terminals.

D. CARRIER PHASE RELAYS

1. In most of the schemes under consideration, the same phase relays that provide carrier protection also provide back-up protection. Thus, these relays must be set to provide for both functions. In general, the requirements do not conflict. However, it is well to remember that the carrier portions of this scheme provide the best part of the overall line protection and this should greatly influence the relay settings.

2. Since high-speed carrier stopping and tripping depend on the operation of the carrier-stopping and tripping units, these units at all terminals must be set to pick up for all multiphase faults in the protected line section for all practical system conditions. It should be noted that on three-terminal lines, an internal fault near one terminal will appear to be farther away, impedance-wise, from the relay terminal than it actually is because of the current infeed from the second remote terminal. This must be considered when setting the reach of the carrier stop and trip units.

$$Z_{A-C} = Z_{A-J} + \left(1 + \frac{I_B}{I_A}\right) Z_{J-C}$$

where A, B, C are the three terminals, and J is the junction of the three branches as shown in Fig. 9.

3. Because successful carrier blocking for external phase faults is essential to prevent false tripping, the carrier starting units for external faults must reach farther than the reach of the carrier-stopping and tripping units at the remote terminals. An offset setting is required on all mho-type carrier-starting units to insure that these units will pick up and stay picked up to maintain carrier transmission on nearby, zero-voltage external faults.

4. Out-of-step blocking is obtained by virtue of the sequence of operation between the measuring unit of the out-of-step blocking relay and the carrier tripping unit. This sequence of operation is measured by the time-delay auxiliary OB unit in the out-of-step-blocking relay. The OB unit has a four-cycle time delay on pickup. The measuring unit of the out-of-step-blocking relay must be set so that its characteristic is larger than, and encircles, that of the carrier tripping unit at the same terminal. Its characteristic must be sufficiently large so that the apparent impedance resulting from a system swing or out-of-step condition will require more than four cycles (on a 60-cycle base) to traverse the distance from the periphery of the blocking relay characteristic to that of the tripping unit characteristic. This will permit out-of-step blocking to get set up. It is important to note that the proper setting for the measuring unit of the out-of-step blocking relay will depend on the rate of the fastest swing and the setting of the corresponding tripping unit.

5. The PJC overcurrent fault detectors that are recommended when line-side potentials are employed, are not mechanically capable of being operated in the picked-up position continuously. For this reason, they should be set above maximum full load current. However, the setting should be as low as possible to insure fast operation during fault conditions. Note, CHC fault detector relays are available that are suitable for operation continuously picked up. These may be set below full load current.

E. BACK-UP PHASE RELAYS

1. The high-speed, first-zone units must be set short enough so that they do not reach beyond any of the remote terminals, even under conditions of minimum infeed.

2. The second-zone, time-delay units should be set with a reach that is long enough to insure that they will operate for phase faults anywhere in the protected line section. On three-terminal lines the effects of infeed must be considered. See section D-2 above. The second-zone time setting of the RPM relay should be as short as possible but long enough to insure time coordination for faults in adjacent line sections as far away as the reach of their second-zone units.

3. The third-zone time-delay units of the GCX17A and B relays control the RPM timer. For this reason, the reach should be at least somewhat longer than the associated second-zone units. In GCXY and GCY12A and CEB17 relay applications, the third-zone units "look" in the reverse direction; and while they control the associated RPM timing relay, so do the second-zone units. For this reason, the reach setting is based on the requirements to start carrier. See section D-3 above. The third-zone time setting of the RPM relay should be set to insure time coordination with relays on the adjacent line sections, with due regard to the reach settings of those relays.

F. GENERAL

1. Under no conditions should the settings of any of the phase relays, including the out-of-step-blocking relay, be such that load can cause them to operate.

2. All phase relays employed in these schemes are supplied with phase-to-phase potentials and the currents of the same 2 phases. Thus, they reach the same distance for all types of multi-phase faults.

3. In no case should any relay be set outside of the rated ranges as given in the instruction book.

4. All values of ohms, amperes and volts used in these tables are in terms of secondary quantities; ohms are phase-to-neutral values.

A well-planned and coordinated relaying system will provide secure and reliable protection.

TABLE I

FUNCTIONS THAT ARE COMMON TO ALL SCHEMES

DEVICE	DEV. NO.	UNIT	FUNCTION
BCA11AV	85	GD2X	Controlled by 67GC/GD. In turn it de-energizes 85/RH coils and stops local carrier. It is picked up only for ground faults in the tripping direction. Has 6-9 ms pickup and fast dropout.
		MX	Controlled by 21/M2or 21/M or 21-Z2 depending on scheme used. In turn it provides the same functions as GDX except for multi-phase faults.
		R	Picks up on receipt of a carrier signal to block local tripping. Has fast pick-up and drop-out times.
		RH	Drops out for faults in tripping direction. RH & R are wound on same core. The normally closed contacts labelled R are closed when both R & RH are de-energized, and they are open when either R or RH or both are energized.
		T	Provides target indication for carrier trip.
NGA15B	85Y	GDY	Purchased only for a terminal, on a 3-terminal line, where current flowing in toward an internal fault is above G1 pickup but below G2 pickup. Controlled by 67GD. In turn it by-passes G1 contact to remove carrier started by G1, thus permitting tripping of other terminals if current is flowing in at both of them.
NAA22L (Optional	85X	RA	Picks up on receipt of a carrier to give an alarm. Has fast pick-up and drop-out times.
		RI	Initiates Automatic Reclosing. Holds off carrier for approximately 8 cycles after a trip. Has fast pick-up and 7-9 cycle drop-out times.
16SB1CB4B21	TS		Switch for testing the carrier channel.
JO328		Rheostat	Provides reserve signal (RS) test of carrier channel in R.S. position of switch.
Microammeter			Reads strength of received signal in REC position of switch, during RS test.
White Lamp			Identifies source of carrier signal if more than 1 carrier terminal is connected to same alarm bell.
Tel Jack			For voice communication.
16SB1DB211	CCS		Channel cutout switch for removing directional comparison and instantaneous reclosing from service. Backup relaying remains in service.
JBCG51E or JBCG53E or JBCG77E	67GB	D	Directional unit. Provides directional control for IOC & TOC listed directly below.
		IOC	Directional Instantaneous Overcurrent Unit. Provides high-speed back-up protection on ground faults.
		TOC	Directional Time Overcurrent Unit. Provides time delay back-up protection on ground faults.
CLPG12C	67GC	GD	Ground Directional Unit in Carrier Scheme. With G2 it operates on ground faults in the tripping direction to control GD2X and initiate carrier tripping. Also operates in conjunction with 67GC/G1 for ground faults in the non-tripping direction to control 67GC/GD1X.
		G1	Non-directional overcurrent unit that starts carrier on ground faults. It also operates in conjunction with 67GC/GD to control 67GC/GD1X.
		G2	Non-directional overcurrent unit. It operates in conjunction with 67GC/GD to provide carrier stopping and tripping for ground faults in the tripping direction.
		GD1X	Auxiliary relay with 1-2 cycle pick-up and 5 cycle drop-out time. Controlled by 67GC/GD and 67GC/G1 to prolong carrier transmission on single-phase-to-ground faults in the non-tripping direction.
		T	Target to indicate a ground fault carrier trip.

TABLE II

APPLIES TO CEY16B - CEB17A-2- OR 3-TERMINAL LINE APPLICATIONS DWG. 7021B99CA

CEY16B	21	M	Directional Mho Distance Relay. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping.
CEB17B	68	RM	Offset Mho Distance Relay. Operates to start carrier transmission.
CHC12A	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. May safely be set below load current and picked up continuously. With line-side potential, use this or PJC.
PJC31C	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. Should not be set below maximum load current. With line-side potential, use this or CHC.

TABLE III

APPLIES TO CEY-CEB PHASE RELAYS IN 2- OR 3-TERMINAL LINE APPLICATIONS DWG. 7381B42CA

DEVICE	DEV. NO.	UNIT	FUNCTION
CEY15A	21-M1		Directional Mho Distance Relay - Operates to provide first zone back-up protection for multi-phase faults.
CEY16A	21-M2		Directional Mho Distance Relay - Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
CEB17A	21-M3		Offset Mho Distance Relay - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM Timing Relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
CHC12A	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. May safely be set below load current and picked up continuously. With line-side potential, use this or PJC.
PJC31C	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. Should not be set below maximum load current. With line-side potential, use this or CHC.
RPM21D	21X	TX TU	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from phase-distance relays 21-M2 or 21-M3. Timing unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
CEB12B	68	MB OB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping. Auxiliary unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2 and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21-M2 contacts close and short down 68/OB before 68/OB gets picked up, as in the case of an internal fault.

TABLE IV

APPLIES TO GCY12A 2- OR 3-TERMINAL LINE APPLICATIONS - DWG. 7021B81CA

GCY12A	21	M1	Directional Mho Distance Unit - Operates to provide first zone back-up protection for multi-phase faults.
		M2	Directional Mho Distance Unit - Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-2 to provide second zone backup protection for multi-phase faults.
		OM3	Offset Mho Distance Unit - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
CHC12A	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. May safely be set below load current and picked up continuously. With line-side potential, use this or PJC.
PJC31C	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. Should not be set below maximum load current. With line-side potential, use this or CHC.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from phase-distance relays.
		TU	Solenoid Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
		T1, T2, T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CEB12B	68	MB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2, and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M2 contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE V

APPLIES TO GCX17A OR -B 2-TERMINAL LINE APPLICATIONS - DWG. 7021B82CA

DEVICE	DEV. NO.	UNIT	FUNCTION
GCX17A, -B, -M, or -N	21	M	Directional Mho Distance Unit. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide third zone back-up protection for multi-phase faults. Operates in conjuction with 21/0 to provide first zone back-up protection for multi-phase faults. Operates in conjunction with 21X/TU-2 to energize 21/OX which in turn switches the reach of 21/0 from zone 1 to zone 2.
		O	Non-directional Reactance Distance Unit. Operates in conjunction with 21/M to provide first-zone back-up protection for multi-phase faults. Also operates in conjunction with 21/M, 21/OX and 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
		OX	Auxiliary Transfer Unit. Operates in conjunction with 21M and 21X/TU-2 to switch the reach of 21/0 from first to second zone.
		S	Auxiliary Coordinating Unit. Purpose and operation described in GCX17A Instruction Book.
		OC	Non-directional Overcurrent Unit. Acts as a fault detector to supervise operation of all multi-phase-fault tripping. Should not be set below maximum load current. Present only in GCX17B or N.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from Phase-distance relays.
		TU	Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction ith phase-distance relays.
		T1,T2,T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CFZ17A	68	Z_{31} -Z_{23} Z_{12}	Non-directional Impedance Distance Units. Start carrier on multi-phase faults. Also operate in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pick-up. Operates in conjunction with 68/Z_{31}, 68/Z_{23} and 68/Z_{12} to block zone 1, zone 2 and carrier tripping by phase relays on system swings and out-of-step. This blocking is prevented in the event that 21/M contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE VI

APPLIES TO GCXY ON 2- OR 3-TERMINAL LINE APPLICATIONS - DWG. 7021B83CA

GCXY	21	OM3	Offset Mho Distance Unit - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
		M2	Directional Mho Distance Unit - Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21/01 to provide first zone back-up protection for multi-phase faults. Operates in conjunction with 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
		O_1	Non-directional Reactance Distance Unit - Operates in conjunction with 21/M2 to provide first zone back-up protection for multi-phase faults.
		S	Auxiliary Coordinating Unit - Purpose and operation described in GCXY instruction book.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from phase-distance relays.
		TU	Solenoid Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
		T1,T2,T3	Targets used in conjunction with zones 1, 2, and 3 of the phase-distance relays.
CEB12B	68SB	MB	Operates in conjunction with 68SB/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68SB/MB to block zone 1, zone 2, and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE VII

GROUND RELAY SETTINGS - ALL SCHEMES

DEVICE	DEV. NO.	UNIT	TWO TERMINAL LINES	THREE TERMINAL LINES
JBCG52E or JBCG54E or JBCG78E	67GB	D	No adjustment Available	No Adjustment Available
		IOC	Set pickup no lower than 125% of the maximum current in the relay for a ground fault at the remote terminal with the remote breaker closed.	Assume one of the remote terminal breakers open and determine the maximum current in the relay for a ground fault at the second remote terminal. Then assume only the second remote terminal breaker to be open and determine the maximum current in the relay for a ground fault at the first remote terminal. Set the pickup no lower than 125% of the greater of the two values obtained.
		TOC	Set pickup no higher than 67% of the minimum single-phase-to-ground-fault current in the relay with the remote breaker closed. Unless local backup is provided at the terminal (s) leading out of the opposite station (s), the settings should be low enough to provide backup for all adjacent line sections in the forward direction, at least sequentially. Set time dial to coordinate with other ground relays on the system.	
CLPG12C	67GC	GD	Set for minimum pickup (maximum sensitivity). Check to insure pickup for all single-phase-to-ground faults on the protected line with line breakers closed on both terminals. Use dual polarization where facilities permit.	Set for minimum pickup (maximum sensitivity). Check to insure pickup for all single-phase-to-ground faults on the protected line with the line breakers closed at all three terminals. Use dual polarization where facilities permit.
		G2	Set pickup no higher than 67% of the minimum single-phase-to-ground-fault current in the relay with the remote breaker closed. Lower pick-up settings are permissible and in most cases desirable for increased speed of operation. However, do not set pickup lower than 125% of the G1 pick-up setting at the remote end of the line.	Set pickup no higher than 67% of the minimum single-phase-to-ground-fault current in the relay with both remote line breakers closed. Lower pick-up settings are permissible and in most cases desirable for increased speed of operation. However, do not set pickup lower than 250% of the G1 pick-up settings at the two remote terminals.
		G1	Set pickup no higher than 80% of the pickup of the opposite terminal's G2 unit.	Set pickup no higher than 40% of the lower of settings of the two opposite terminals G2 units.

TABLE VIII

PHASE RELAY SETTINGS -- CEY16A-CEB17A RELAYS -- 2-TERMINAL LINES -- DWG. 7021B99CA

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY16A	21	M	Set to reach 125-150% of the ohms to the opposite terminal, taking the line impedance angle into consideration. 125% tends to give slow operation for end-zone faults, so it would be used only to avoid false operation on swings, or operation of 68SB on maximum load with the setting which results from the setting chosen for 21-M.
CEB17A	68CB	RM	Set for 0.5 ohm offset. Set the reach for not less than 1.25 x [(Setting of M at opposite end) + 0.5-(ohms of protected line section)].
CEB12B	68SB	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68SB should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68SB should be the available value nearest to half the difference between the ohmic settings of 68SB and 21. The reach of 68SB must not be great enough to cause operation by maximum load current.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE IX

PHASE RELAY SETTINGS -- CEY16A-CEB17A RELAYS -- 3-TERMINAL LINES -- DWG. 7021B99CA

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY16A	21	M	Set to reach 125-150% of the maximum apparent impedance to either of the other terminals, including the effect of infeed and line-impedance angle. 125% tends to give slow operation for end-zone faults, so it would be used only to avoid false operation on swings. 150% is the preferred settings. However, the setting should not be long enough to require a setting on 68SB so high that it will be picked up by maximum load.
CEB17A	68CB	RM	For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the 2 values of desired reach. Minimum reach = 1.25 [(Setting of M at opposite end) + 0.5-(ohms of line section between the 2 closed terminals)].
CEB12B	68SB	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68SB should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load current, mentioned below. The offset tap of 68SB should be the available value nearest to half the difference between the ohmic settings of 68SB and 21. The reach of 68SB must not be great enough to cause operation by maximum load current. If this requirement cannot be met, the setting of 21 must be reduced (which will result in sequential tripping), and the CEB14 should be substituted to prevent 68SB/OB getting set up for a particular range of fault locations.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE X

PHASE RELAY SETTINGS -- CEY15A-CEY16A-CEB17A RELAYS -- 2-TERMINAL LINES -- DWG. 7381B42CA
OR GCY12 RELAYS -- 2-TERMINAL LINES -- DWG. 7021B81CA

CEY15A or GCY12	21-M1 21	M1	Set for 80-90% of the impedance to the remote end of the line, taking account of the impedance angle of the line.
CEY16A or GCY12	21-M2 21	M2	The minimum setting is 125% of the impedance of the protected line section, taking account of the line impedance angle. The maximum setting is the least of 3 maximums, determined as follows: The first maximum is 80% of the total impedance (not reactance) ohms to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of the line-impedance angle. The second maximum is a setting such that the unit will not trip on the maximum swing from which the system might recover (usually considered 120°). The third maximum is a setting which will permit choosing a setting of MB such that MB will not operate due to maximum load. The best setting is (approximately) the square root of the product of the (greater) minimum and the least maximum.
CEB17A or GCY12	21RM3 21	OM3	The setting of this unit depends on the setting of the M2 unit at the other terminal. Set CEB17 for 0.5 ohm offset, or GCY for 1 ohm offset. Set the reach for not less than 1.25 [(Setting of M2 at opposite end) + (offset ohms) - (ohms of protected line section)].
RPM21D or RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of this 21-M2, plus the desired margin.
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the station where relays are, within reach of this 21R3 or 21/OM3, plus the desired margin (margin usually 10 cycles).
CEB12B	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21-M2 or 21/M2 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M subject to the limitation due to load current, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load current.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XI

PHASE RELAY SETTINGS -- CEY15A-CEY16A-CEB17A RELAYS -- 3-TERMINAL LINES -- DWG. 7381B42CA
OR GCY12 RELAYS -- 3-TERMINAL LINES -- DWG. 7021B81CA

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY15A or GCY	21-M1 21	M1	Set for 80-90% of the impedance to the nearer remote terminal, taking the line impedance angle into consideration. Do not include the effects of infeed.
CEY16A or GCY12	21-M2 21	M2	Set to reach 110-150% of the maximum apparent impedance to either of the other terminals including the effects of infeed and line-impedance angle. 110% gives slow operation for end-zone faults, so it would be used only to prevent false operation on swings or to avoid excessive reach from the standpoint of coordination with relays on other lines out of the other stations. 150% is the preferred setting. However, the setting should not be long enough to require a setting on 68SB so high that it will be picked up by maximum load.
CEB17A or GCY12	21RM3		For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the two values of desired reach. Minimum reach = 1.25 [(Settings of M at opposite end) + 0.5 - (ohms of line section between the two closed terminals)].
RPM21D or RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of either of the other two stations, within reach of M2 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of this station, within reach of OM3 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
CEB12B	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21-M2 or 21/M2 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the two characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68 shouuld be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load. If this requirement cannot be met, the setting of 21 must be reduced (which will result in sequential tripping), and the CEB14 should be substituted to prevent 68/OB getting set up for a particular range of fault locations.
CHC12	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferable 58% of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XII

PHASE RELAY SETTINGS -- GCX17-CFZ17 RELAYS -- 2-TERMINAL LINES -- DWG. 7021B82CA

GCX17	21	M	Set for at least 125% of the impedance to the opposite terminal, taking account of the line impedance angle. However, 125% tends to give slow operation for end-zone faults, so at least 150% is preferred. The setting must not be large enough to permit operation by maximum load, or to permit response to a severe fault on an adjacent phase. The setting is also influenced by the fact that if there is no local back-up relaying on other lines out of the opposite-terminal, it is desirable to have M provide zone-3 protection out to 80% of the shortest zone-2 reach on any of those lines, taking account of only the minimum reliable infeed at the opposite station.
		O_1	Set for 80-90% of the reactance to the opposite terminal, for zone-1 protection.
		O_2	Set for 80% of the total reactance to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of only the minimum reliable infeed at the opposite station.
		OC	The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.
CFZ17	68	Z_{1-2} Z_{2-3} Z_{3-1}	The maximum setting is one which will permit the relay to reset at maximum load, following a swing; therefore the maximum suggested setting is 80% of the impedance corresponding to maximum load. If out-of-step blocking is not used, the minimum setting = 1.25 [(Setting of M at opposite end) - (ohms of protected section)]. If out-of-step blocking is used, the minimum setting for that purpose should be determined by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21/M by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of 21/M. Then use the higher of the minimums found for the carrier starting function and for the out-of-step blocking function, subject to the maximum determined by the load, mentioned above.
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of this 21/02, plus the desired margin.
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of this 21/M, plus the desired margin (margin usually 10 cycles).

TABLE XIII

PHASE RELAY SETTINGS -- GCXY -- 2-TERMINAL LINES -- DWG. 7021B83CA

DEVICE	DEV. NO.	UNIT	SETTINGS
GCXY	21	01	Set for 80-90% of the reactance to the opposite terminal, for zone-1 protection
		M2	The minimum setting is 125% of the impedance of the protected line section, taking account of the line-impedance angle. The maximum setting is the least of 4 maximums, determined as follows: The 1st maximum is 80% of the total impedance (not reactance) ohms to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of the line-impedance angle. The 2nd maximum is a setting which will just not permit response to a severe adjacent-phase fault. The 3rd maximum is a setting such that the unit will not trip on the maximum swing from which the system might recover (usually considered 120°). The 4th maximum is a setting which will permit choosing a setting of MB such that MB will not operate due to maximum load. The best setting is (approximately) the square root of the product of the minimum and the least maximum.
		OM3	The setting of these units depends on the line impedance and the M2 setting at the opposite terminal. Set for not less than 1.25 [(Setting of M2 at opposite end) + (OM3 offset ohms) - (ohms of protected line section)].
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of 21/M2, plus the desired margin (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the station where these relays are, within reach of this 21/OM3, plus the desired margin (margin usually 10 cycles)
CEB12B	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68SB must not be great enough to cause operation by maximum load.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 68% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XIV

PHASE RELAY SETTINGS -- GCXY -- 3-TERMINAL LINES -- DWG. 7021B83CA

DEVICE	DEV. NO.	UNIT	SETTINGS
GCXY	21	01	Set for 80-90% of the reactance to the nearest other terminal. Do not include the effects of infeed.
		M2	The minimum setting is 110% of the maximum apparent impedance to either of the other terminals including the effect of infeed and line-impedance angle. The maximum setting is the least of 4 maximums, determined as follows: The 1st maximum is 80% of the least total impedance (not reactance) ohms to the end of any zone-1 reach on any other line out of either of the other 2 stations, taking account of the line-impedance angle but omitting the effect of infeed. The 2nd maximum is a setting which will just not permit response to a severe adjacent-phase fault. The 3rd maximum is a setting such that the unit will not trip on the maximum swing from which the system might recover (usually considered 120°). The 4th maximum is a setting which will permit chosing a setting of MB such that MB will not operate due to maximum load. The best setting is (approximately) the square root of the product of the minimum and the least maximum.
		OM3	For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the 2 values of desired reach. Minimum reach = 1.25 [(Setting of M at opposite end) + 0.5 - (ohms of line section between the 2 closed terminals)].
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of either of the other 2 stations, within reach of M2 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of this station, within reach of OM3 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
CEB12B	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load.
CHC12A	50		The setting with a phase-to-phase test connections should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CFP19P		377A103	K-6209274
CFP1 A		0127A9413	K-6209276
CLY16A		0127A9418	K-6209276
CHC12A		0148A3956	K-6209272
CLPG12C		0148A3975	K-6209276
PJC31C		K-6375726	K-6209272
NAA22		0148A4074	K-6209272
CHANNEL CUTOFF SW.	SB1	16SB1DB211	116A130
CHANNEL TEST SW.	SB1	16SB1CB4B21	116A130
LAMPS			K-6151144
RHEOSTAT			418A774 F102
TELEPHONE JACK			K-6400578
MICROAM DO-91 (FLUSH)			A5481699
MICROAM MOD. 301 (SURFACE)			378A914
CARRIER SET 4C527		SEE SHEET #3	
HGA14AM (BACK CONN)		K-6400533	K-6400533
HGA14AL (FRONT CONN)		377A139	377A139

LEGEND			
DEVICE NO	DEVICE TYPE	INCL ELEM	
21	CEY15A		3 PHASE MHO TYPE CARRIER TRIP RELAY
		Ø1-2	PHASE 1-2 UNIT ETC.
		T&SI	TARGET & SEAL-IN UNIT
50	CHC12		INSTANTANEOUS FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
50	PJC31C		INSTANTANEOUS OVERCURRENT RELAY
		T&SI	TARGET & SEAL-IN UNIT
67GC	CLPG12C		CARRIER GROUND RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		G2	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		T&SI	TARGET & SEAL-IN UNIT
68CB	CEB17A		3 PHASE OFFSET MHO CARRIER START RELAY
		Ø1-2	PHASE 1-2 UNIT ETC.
		TR1-2	PHASE 1-2 TRANSACTOR ETC.
68SB	CEB12B		OUT OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		OB	AUXILIARY UNIT TO MB
		TR	TRANSACTOR
85	BCA11AV		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER UNIT OPERATING COIL
		RH	RECEIVER UNIT HOLDING COIL
		GD2X	AUXILIARY TO GD AND G2
		MX	AUXILIARY TO M
		T	TARGET
85X	NAA22		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING UNIT
94	HGA14AM OR AL		AUXILIARY FOR TRIPPING 2 BREAKERS
CCS	SB1		CHANNEL CUTOFF SWITCH
TS	SB1		CHANNEL TEST SWITCH

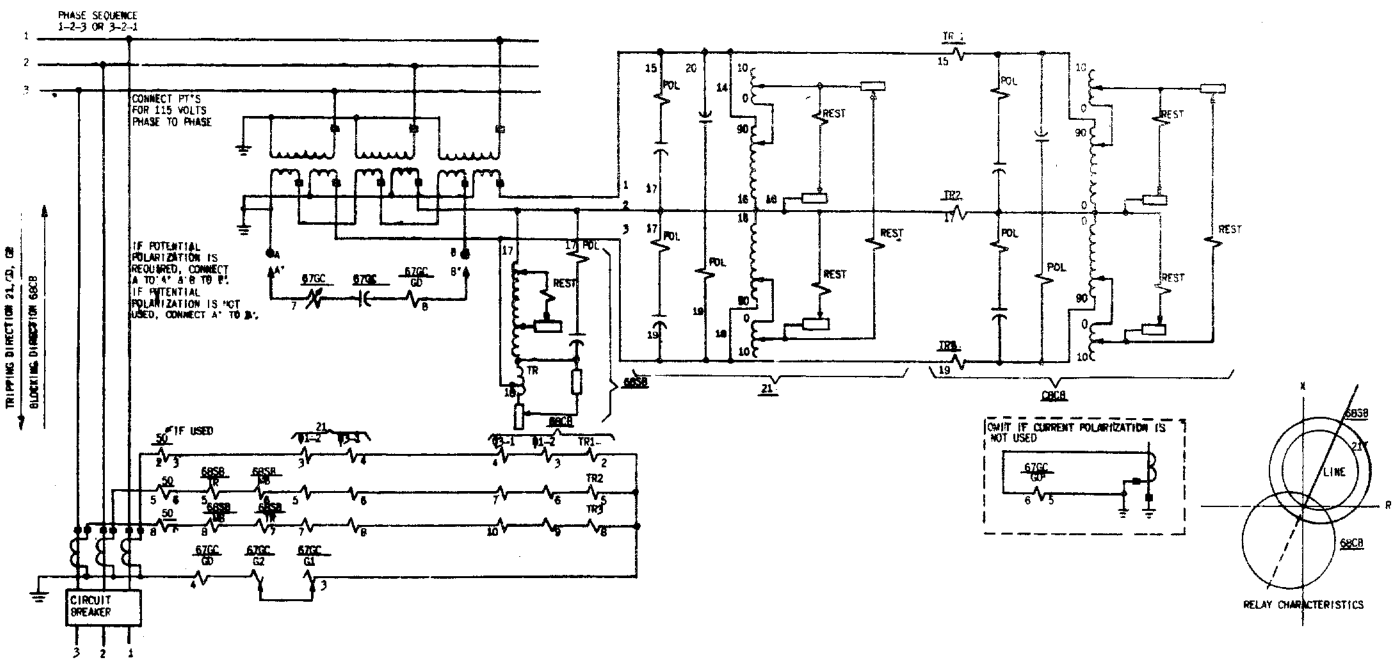
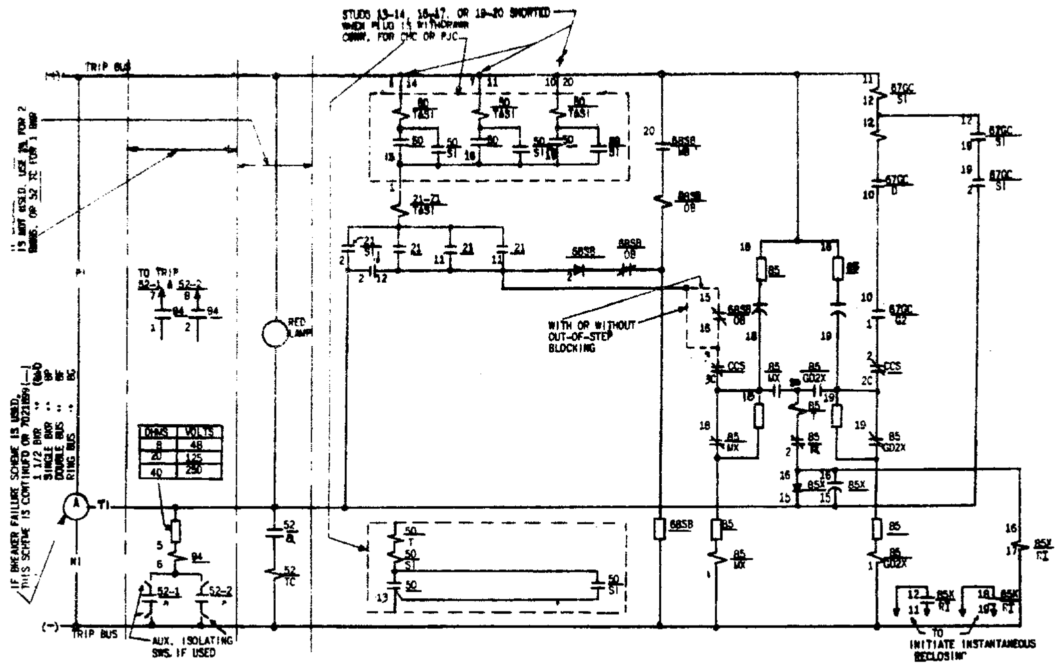


Fig. 10 Overall Elementary Diagram for Carrier-Current Pilot Relayi

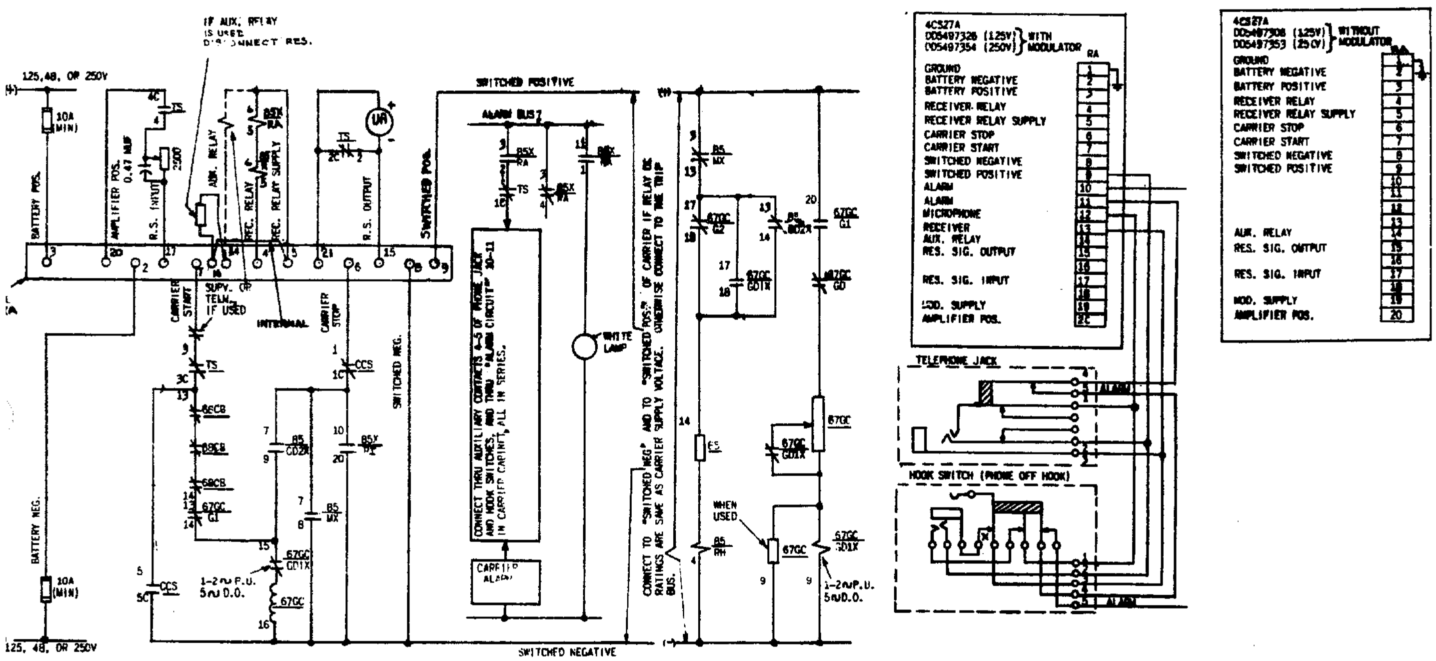


OHMS	VOLTS
8	48
20	125
40	250

CCS	16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH				
CONTACTS HANDLE END		BACK VIEW		
		OFF	ON	
1 1C 2C 2	1		X	
	2		X	
3 3C 4C 4	3		X	
	4		X	
5 5C 6C 6	5	X		
	6	X		
7 7C 8C 8	7		X	
	8		X	

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

TS	16SB1CB4B21 OR SBM EQUIVALENT				
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC	R.S
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					



e Tables II, VIII and IX. (7021B99CA Sh. 1-0, Sh. 2-1, Sh. 3-1)

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INTERNAL CONNS	OUTLINE
BCA11AV		0148A4083	K-6209272
CFB129		377A103	K-6209274
CEB17A		0127A9413	K-6209276
CEY15A		0127A9412	K-6209275
CEY16A		0127A9418	K-6209276
CHC12A		0148A3956	K-6209272
CLPG12C		0148A3975	K-6209276
JBCG51E (INVERSE)		0104A8978	K-6209276
JBCG53E (VERY INVERSE)		0127A9500	K-6209276
NAA22L		0148A4074	K-6209273
RPM21D		0127A9440	K-6209270
RPM21E 48 OR 250V		0127A9441	K-6209270
CARRIER SET 4CS2?		SEE SHEET 3	
CHANNEL CUTOFF SW.	SB1	16SB1DB211	116A130
CHANNEL TEST SW.	SB1	16SB1CB4B21	116A130
MICROAM DO-91 (SURFACE)			0148A3872
MICROAM DO-91 (FLUSH)			A-5481009
RHEOSTAT (RES. SIG. TEST			418A774 FIG2
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
HGA14AL (FRONT CONN)		377A139	377A139
HGA14AM (BACK CONN)		K-6400533	K-6400533
FJC31C		K-6375726	K-6209272

LEGEND			
DEVICE NO	DEVICE TYPE	INCL ELEM	DESCRIPTION
21-M1	CEY15A		3 PHASE - 1ST ZONE MHO RELAY
		ϕ1-2	PHASE 1-2 UNIT ETC.
		TAS1	TARGET & SEAL-IN
21-M2	CEY16A		3 PHASE-2ND ZONE & CARRIER TRIP MHO RELAY
		ϕ1-2	PHASE 1-2 UNIT ETC.
		TAS1	TARGET & SEAL-IN
21-RMB	CEB17A		3 PHASE-3RD ZONE & CARRIER START MHO RELAY
		ϕ1-2	PHASE 1-2 UNIT ETC.
		TR 1	PHASE 1 TRANSACTOR ETC.
		T&S1	TARGET & SEAL-IN
21X	RPM21D		TIMING RELAY
		TU	TIMING UNIT
		TX	AUXILIARY FOR TIMING UNIT
5C	PJC31C		INSTANTANEOUS PHASE FAULT DETECTOR
		TAS1	TARGET & SEAL-IN
50	CHC12		INSTANTANEOUS PHASE FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUXILIARY TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN
		T	TARGET
67GB	JBCG518		GROUND DIRECTIONAL OVERCURRENT RELAY
	OR	D	DIRECTIONAL UNIT
	JBCG53E	IOC	INSTANTANEOUS UNIT
		TOC	TIME DELAY UNIT
		T&SI	TARGET & SEAL-IN
94	HGA14AM	OR AL	AUXILIARY TRIPPING RELAY
68	CFB128		OFFSET MHO OUT OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUXILIARY TO MHO BLOCKING UNIT
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUXILIARY TO GD AND G2
		AX	AUXILIARY TO 21-M2
85X	NA22		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING UNIT
CCS	SB1		CHANNEL CUTOFF SWITCH
TS	SP1		CHANNEL TEST SWITCH

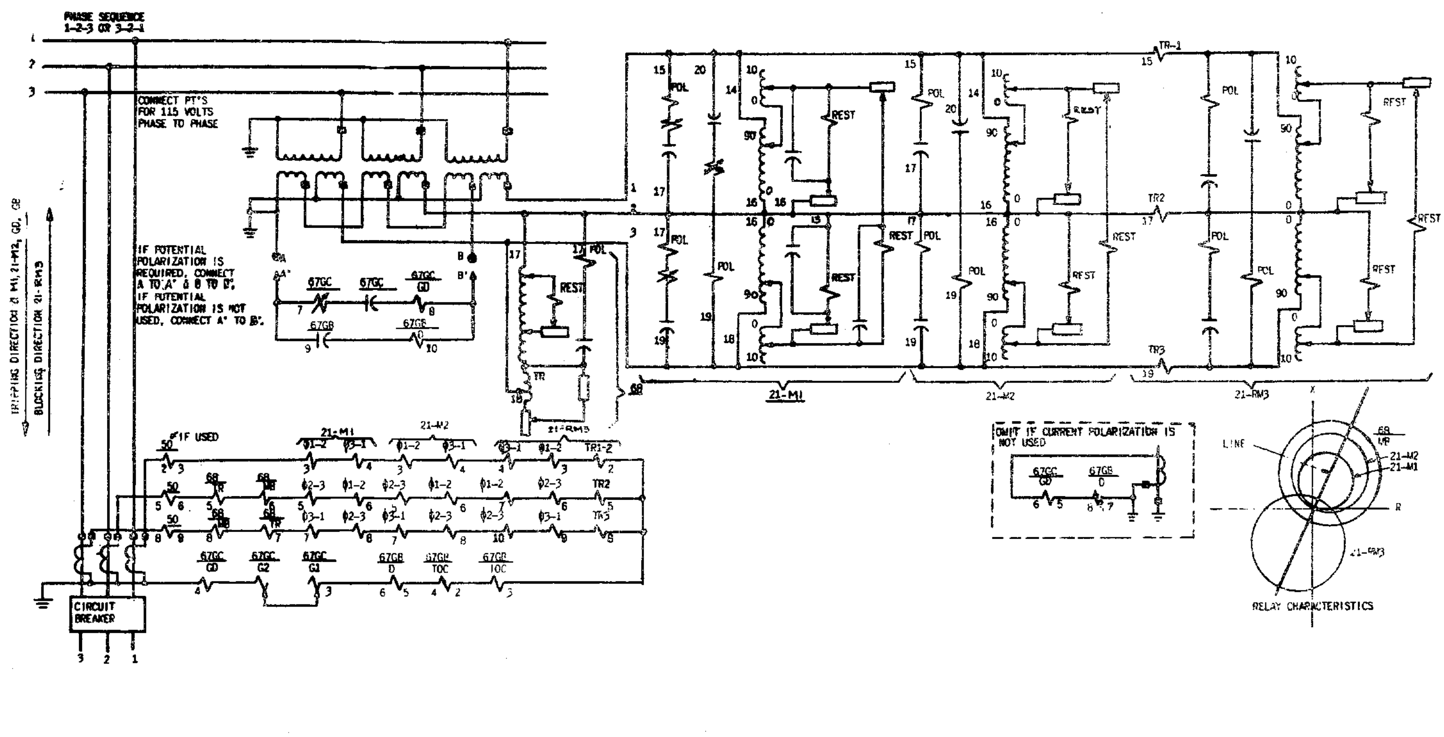
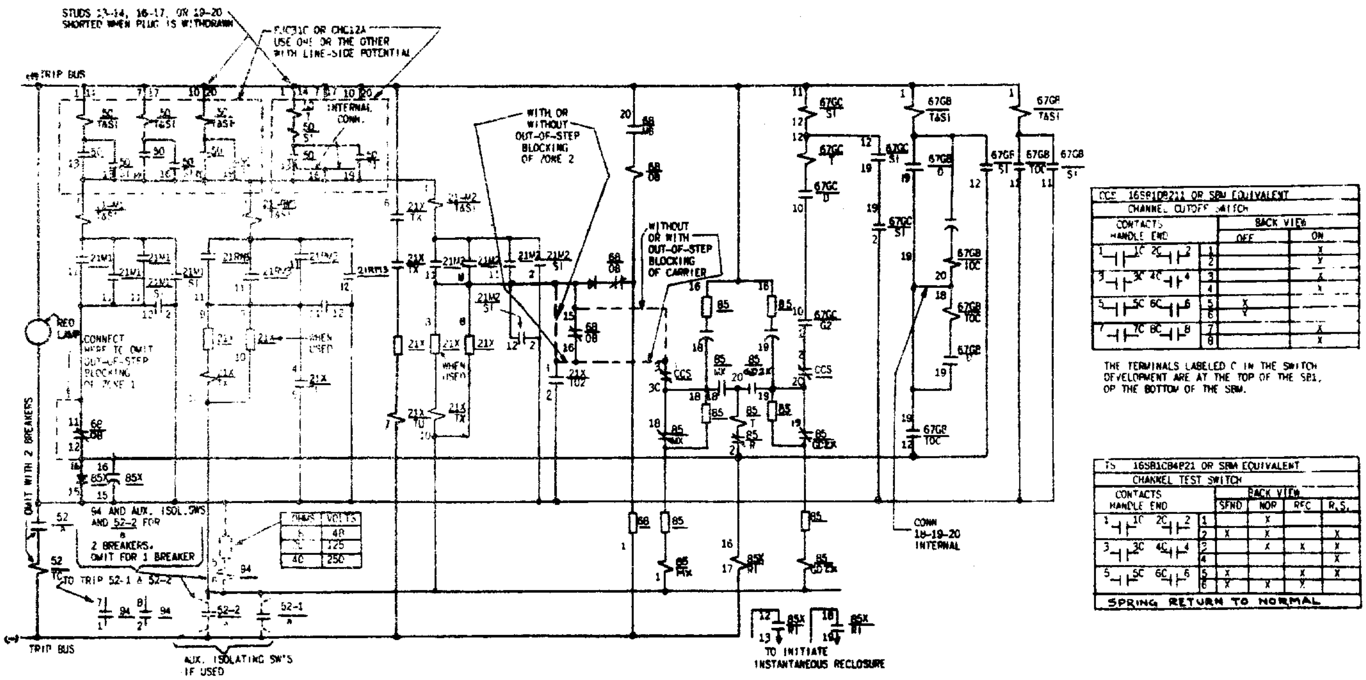
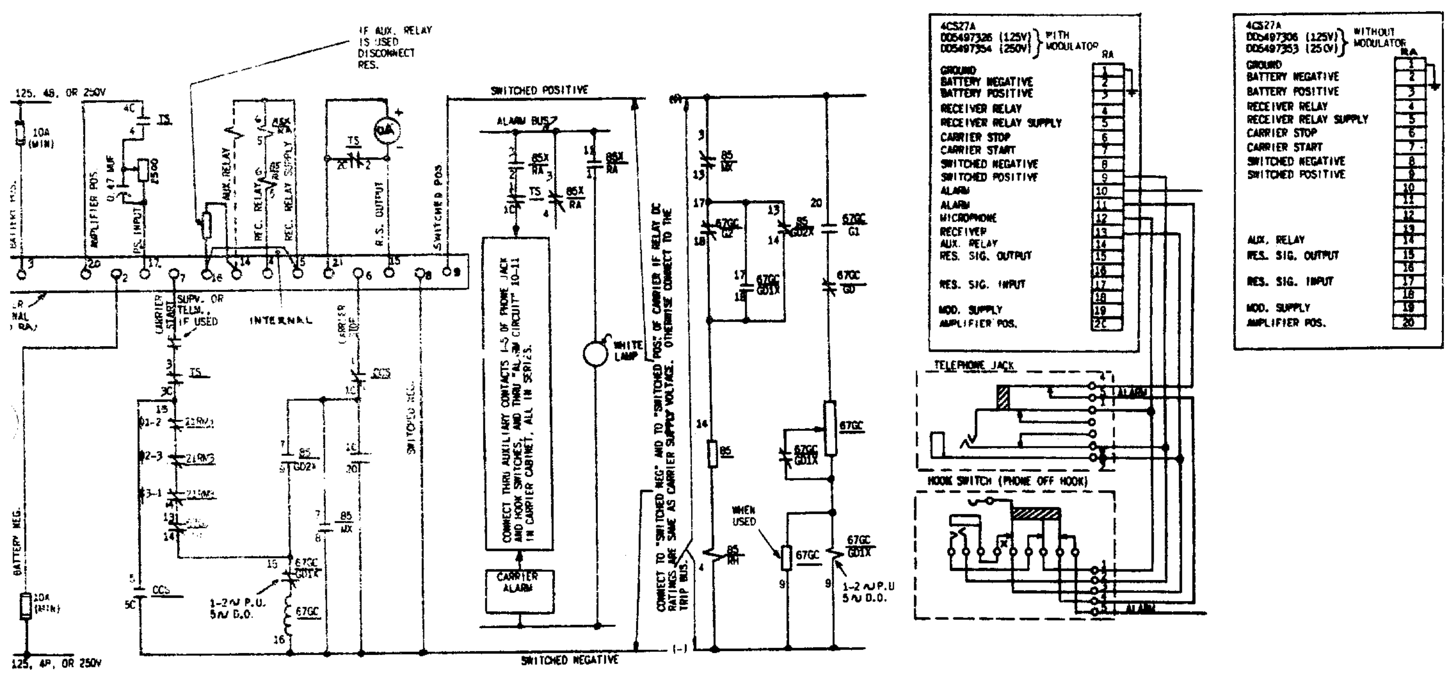


Fig. 11 Overall Elementary Diagram for Carrier-Current Pilot Relaying





See Tables III, X and XI. (7381B42CA Sh. 1-1, Sh. 2-2, Sh. 3-1)

TABULATION OF DEVICES

TYPE OR DESCRIPTION		INT. CONNS	OUTLINE
BCA11AV		0148A4083	K-6209272
CARRIER SET 4CS27		SEE SHEET 3	
CHANNEL CUTOFF SW.	SB-1	16SB1DB211	118A130
CHANNEL TEST SW.	SB-1	16SB1CB4B21	118A130
CEB12B		377A103	K-6209274
CLPG12C		0148A3976	K-6209276
GCY12A		K-6305875	K-6209276
JBCG51E (INVERSE)		0104A8978	K-6209276
JBCG53E (VERY INVERSE)		0127A9500	K-6209276
NAA22L		0148A4074	K-6209272
PJC31C (IF USED)		K-6375726	K-6209272
RHEOSTAT (RES.SIG.TEST)			418A774 FIG.2
RPM11D	125V	K-6209282	K-6209272
RPM11D	48 OR 250V	K-6400680	K-6209272
MICROAM DO-91 (SEMI-FLUSH)			K-6946805
MICROAM DO-91 (SURFACE)			C148A3872
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
AUX CT-JARD			A-6186967
HGA14AM BACK CONN (IF USED)		K-6400533	K-6400533
HGA14AL FRONT CONN (IF USED)		377A139	377A139
CHC12A		0148A3958	K-6209272

LEGEND

DEVICE NO	DEVICE TYPE	INCL ELEM	DESCRIPTION
21	GCY		MHO TYPE STEP DISTANCE RELAY
		M1	1ST ZONE MHO UNIT
		M2	2ND ZONE MHO UNIT
		OM3	3RD ZONE MHO UNIT
		TASI	TARGET & SEAL-IN
		TR	TRANSACTOR
		SI	SEAL-IN
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING ELEMENT
		TX	AUX. FOR TIMING ELEMENT
50	CHC		INSTANTANEOUS PHASE FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
50	PJC		INSTANTANEOUS OVERCURRENT RELAY
		TASI	TARGET & SEAL-IN
52/a			AUX. SWITCH ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME OVERCURRENT UNIT
		TASI	TARGET & SEAL-IN
		SI	SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN UNIT (GROUND)
		T	TARGET
68	CEB		OFFSET MHO BLOCKING RELAY
		MB	OUT-OF-STEP BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUX. FOR OUT-OF-STEP BLOCKING
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUX. TO GD AND G2
		MX	AUX. TO M2
		T	TARGET
85X	NAA		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		R1	RECLOSURE INITIATING AUXILIARY
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
TS			CHANNEL TEST SWITCH

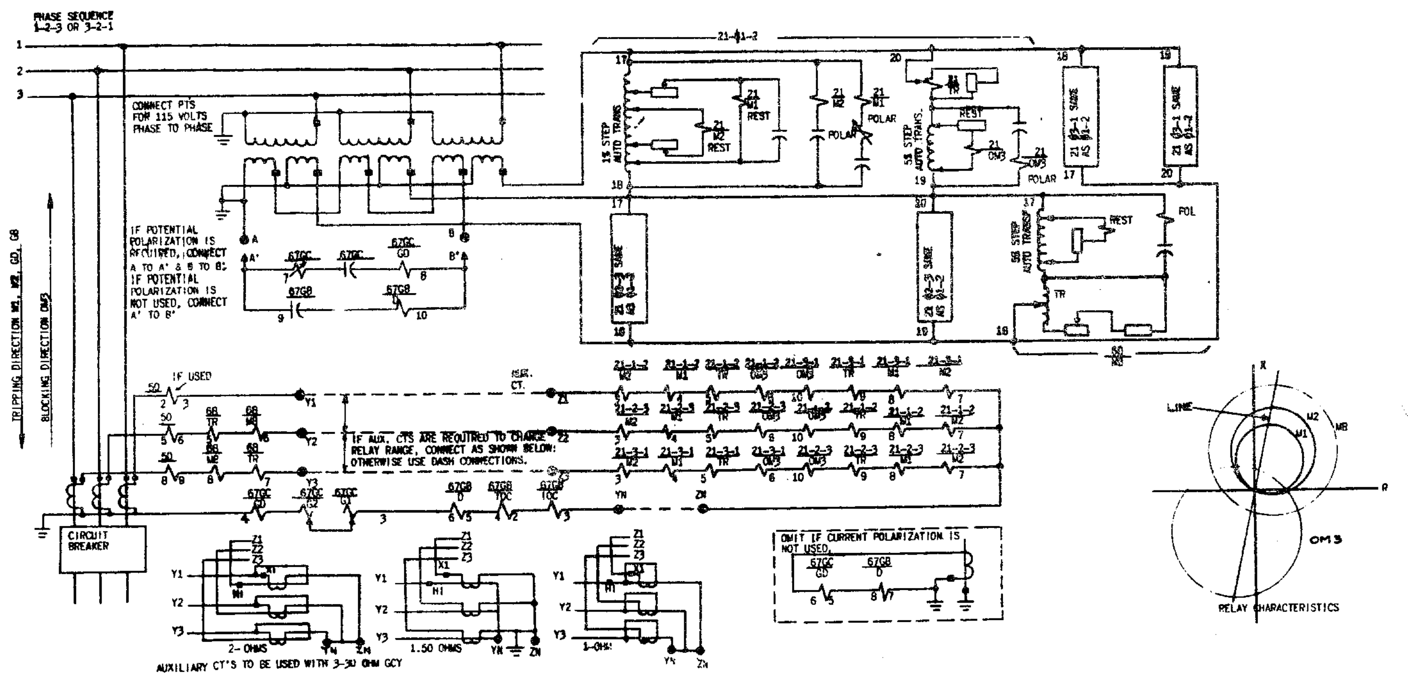
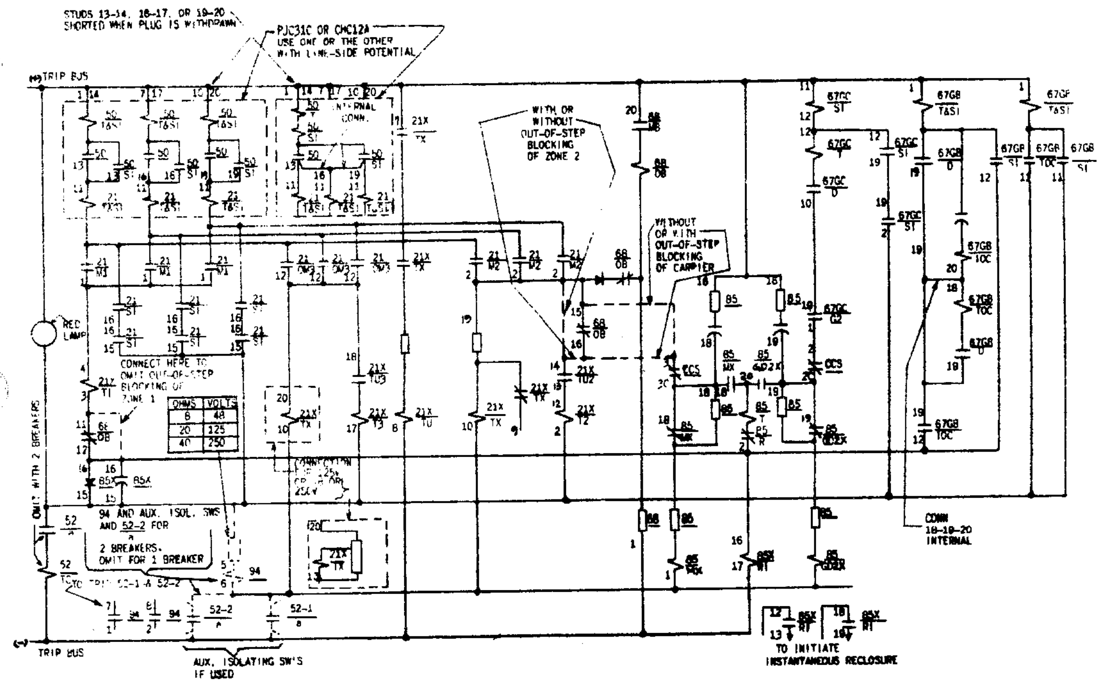


Fig. 12 Overall Elementary Diagram for Carrier-Current Pilot Relaying

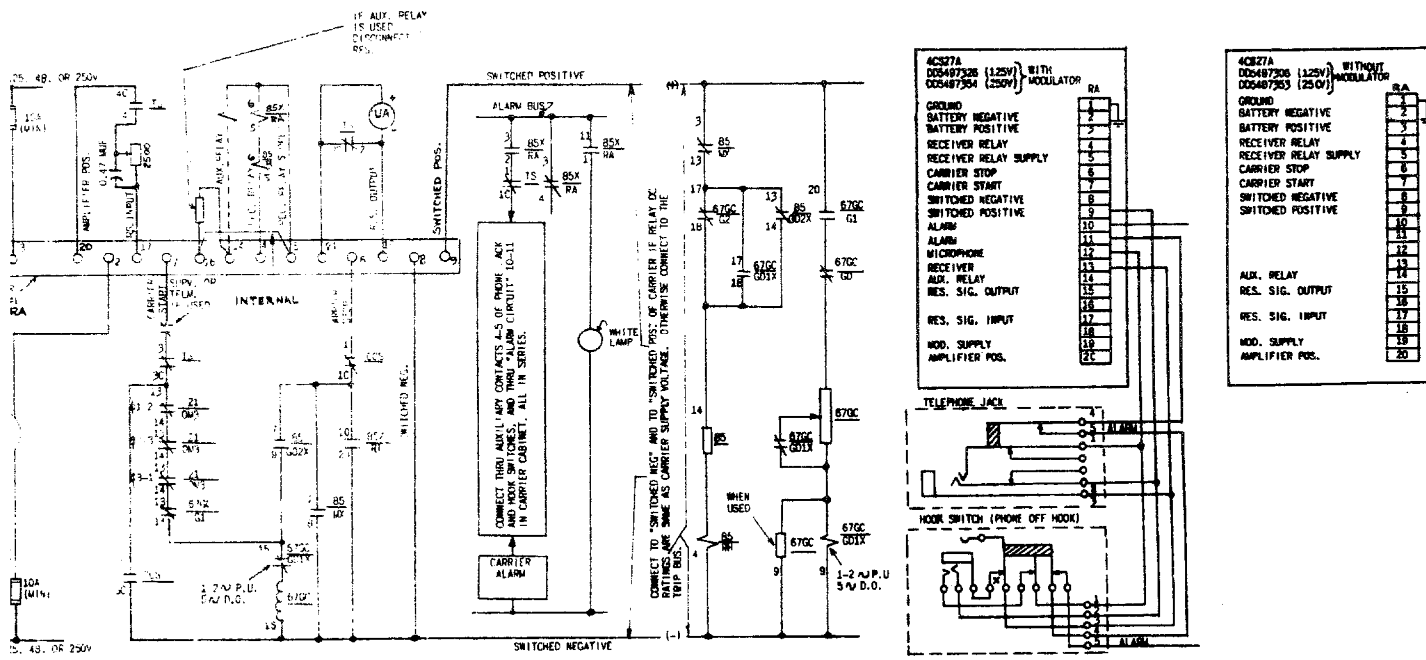


OHMS	VOLTS
6	48
20	125
40	250

CCS 16SB1DB2 11 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

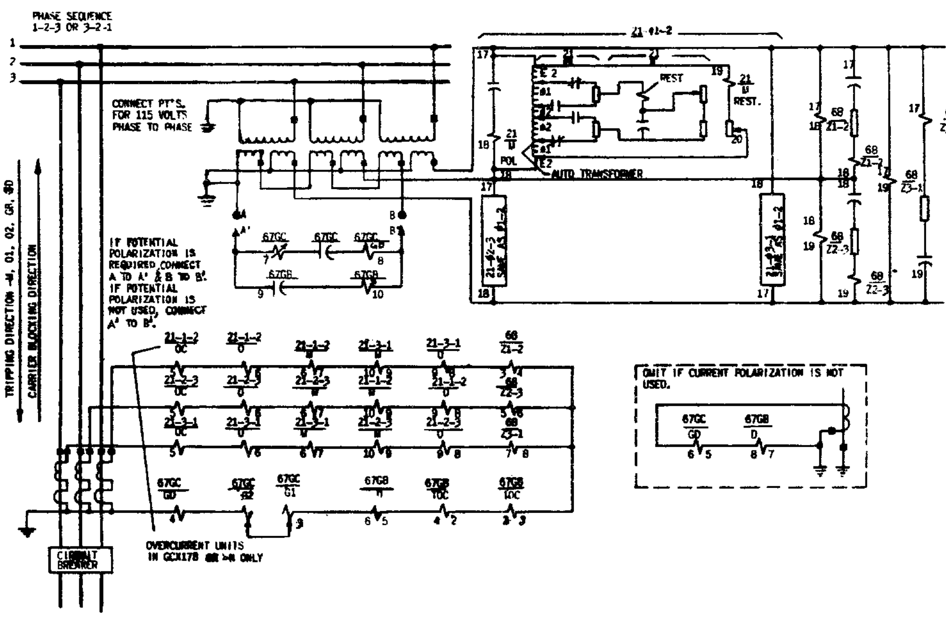
TS 16SB1CB4P21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW SEND	NOR	REC	R.S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					



Tables IV, X and XI. (7021881CA Sh. 1-1, Sh. 2-1, Sh. 3-1)

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AM		0148A4083	K-6209272
CHANNEL CUTOFF SWITCH	SB-1	16SB1DB211	116A130
CHANNEL TEST SWITCH	SB-1	16SB1CB4B21	116A130
CFZ17A		418A767	K-6209276
CLPG12C		0148A3975	K-6209276
GCX17A OR GCX17B		K-6375826	K-6209276
JBCG51E (INVERSE)		0104A8978	K-6209276
JBCG53E (VERY INVERSE)		0127A9500	K-6209276
MICROAM, D091 (SEMI-FLUSH)			K-8946606
NAA22E		0148A4074	K-6209272
RPM11D	125V	K-6209282	K-6209272
RPM11D 48 OR 250V		K-6400680	K-6209272
TEL. JACK			K-6400578
WHITE LAMP			K-6151144
CARRIER SET 4CS29		SEE SHEET 3	
MICROAM [illegible], 302 (SURFACE)			376A914
HGA14AM BACK CONN. (IF		K-6400533	K-6400533
HGA14AL FRONT CONN. (USED		377A139	377A139
RHEOSTAT -RES.SIG.TEST			418A774 FIG.2
GCX17M OR GCX17N		0127A9410	K-6209276

LEGEND			
DEVICE NO.	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING UNIT
		TX	AUX. FOR TIMING UNIT
21	GCX		REACTANCE-TYPE STEP DISTANCE RELAY
		M	MHO-TYPE STARTING UNIT
		O	REACTANCE-TYPE OHM UNIT
		OX	ZONE-TRANSFER AUXILIARY FOR O
		S	COORDINATING AUXILIARY RELAY
		T&SI	TARGET & SEAL-IN
52/a			AUX. SWITCH ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS OVERCURRENT UNIT
		TOC	TIME OVERCURRENT UNIT
		T&SI	TARGET & SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GDIX	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN UNIT (GROUND)
		T	TARGET
68	CFZ		FAULT DETECTOR & OUT-OF-STEP RELAY
		OB	OUT-OF-STEP BLOCKING AUXILIARY
		Z1-2, Z2-3, Z3-1	IMPEDANCE UNITS (1 PER PHASE)
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GDMX	AUX. TO GD AND G2
		MX	AUX. TO M
		T	TARGET
85X	NAA		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING AUXILIARY
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
TS			CHANNEL TEST SWITCH



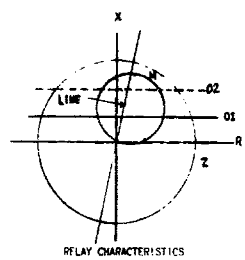
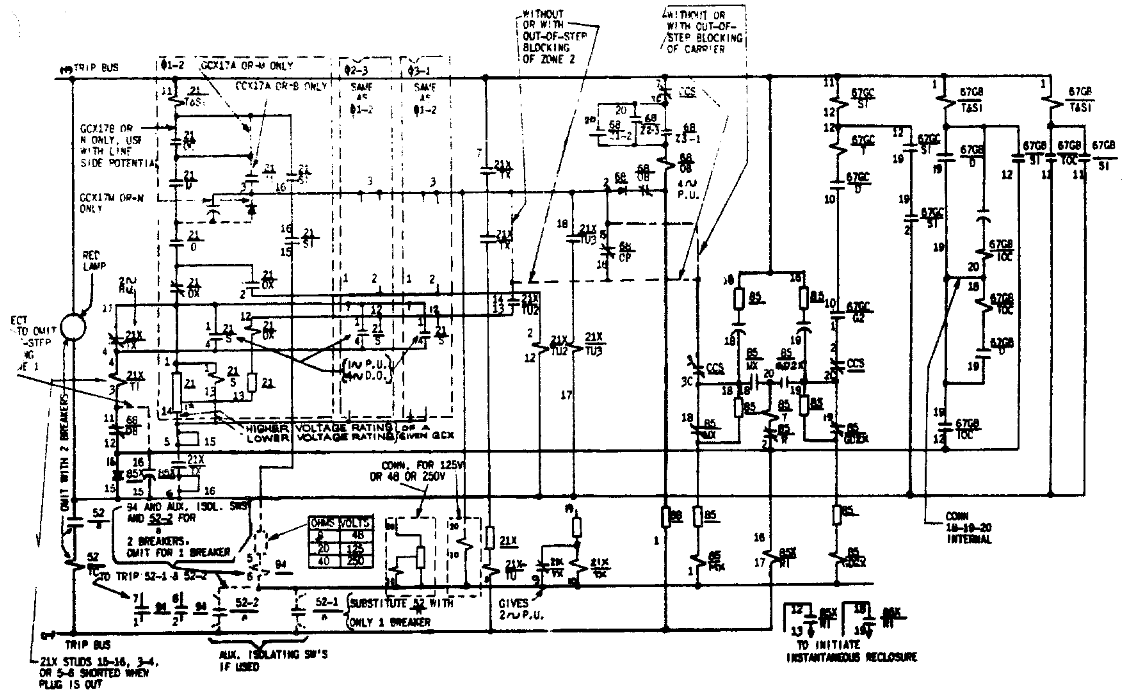


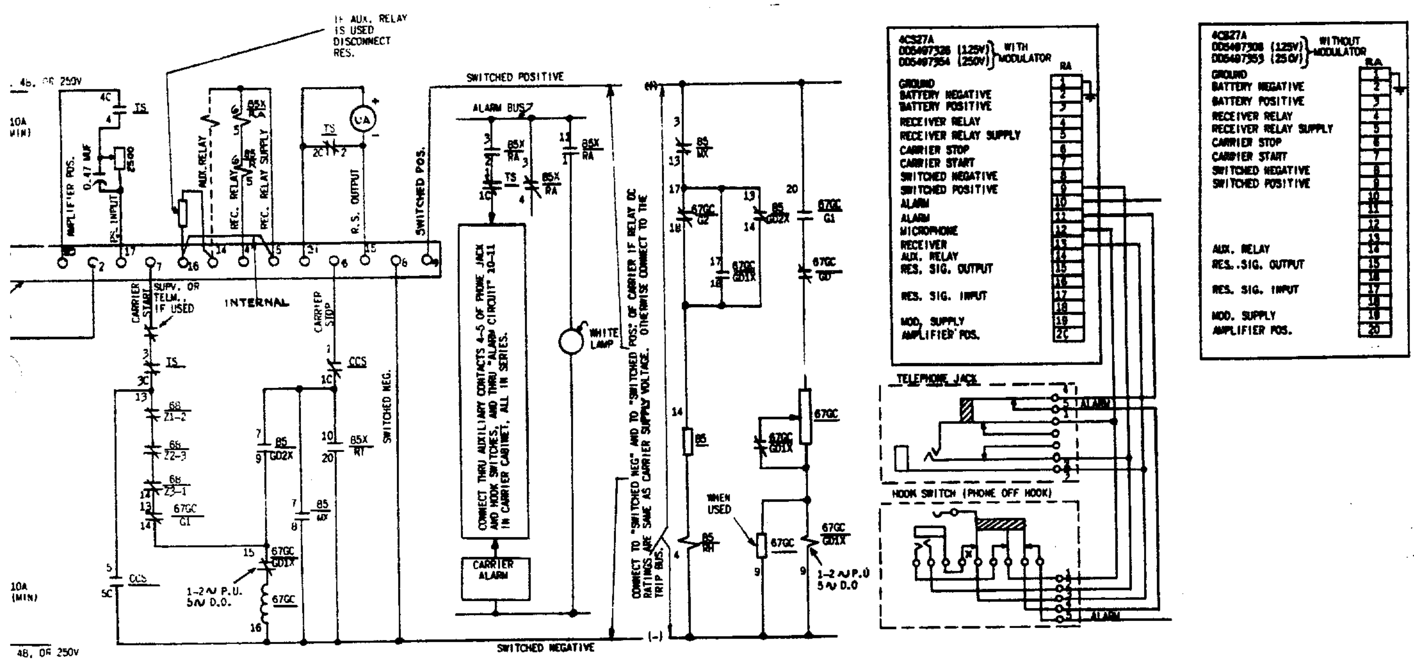
Fig. 13 Overall Elementary Diagram for Carrier-Current Pilc



CCS- 16SB1DB21A OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1-1C 2C-2	1		X
	2		X
3-3C 4C-4	3		X
	4		X
5-5C 6C-6	5	X	
	6	X	
7-7C 8C-8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

TS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC	R.S.
1-1C 2C-2	1		X		
	2	X	X		X
3-3C 4C-4	3		X	X	X
	4				X
5-5C 6C-6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					



laying. See Tables V and XII. (7021B82CA Sh. 1-1, Sh. 2-3, Sh. 3-1)

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS	OUTLINE
BCA11AV		014BA4083	K-6209272
CARRIER SET 4CS27		SEE SHEET 3	
CHANNEL CUTOFF SW.	SB-1	16SB1DB211	116A130
CHANNEL TEST SW.	SB-1	16SB1CB021	116A130
CEB12B		377A103	K-6209274
CLPG12C		014BA3975	K-6209276
GCXY11A		0165A6060	K-6209276
JBCG51E (INVERSE)		0104A8978	K-6209276
JBCG53E (VERY INVERSE)		0127A9500	K-6209276
NAA22L		014BA4074	K-6209272
PJC31C (IF USED)		K-6375726	K-6209272
RHEOSTAT (RES.SIG.TEST)			418A774 FIG.2
RPM11D	125V	K-6209282	K-6209272
RPM11D	48 OR 250V	K-6400680	K-6209272
MICROAM.DO-91 (SEMI-FLUSH)			K-6946606
MICROAM.DO-91 (SURFACE)			014BA3872
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
AUX CT-JARD			A-9188967
HGA14AV BACK CONN (IF USED)		K-6400533	K-6400533
HGA14AL FRONT CONN (IF USED)		377A139	377A139
CHC12A		014BA3956	K-6209272
RECT. FOR TX 295B233 G-14	125V		418A964
RECT. FOR TX 295B233 G-15	250V		418A964

LEGEND			
DEVICE NO	DEVICE TYPE	INCL ELEM	DESCRIPTION
21	GCXY		REACTANCE TYPE STEP DISTANCE RELAY
		01	1ST ZONE REACTANCE TYPE OHM UNIT
		M2	2D ZONE MHO UNIT
		OM3	3D ZONE MHO UNIT
		S	COORDINATING AUXILIARY RELAY
		T&SI	TARGET & SEAL-IN
		SI	SEAL-IN
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING ELEMENT
		TX	AUX. FOR TIMING ELEMENT
50	CHC		INSTANTANEOUS PHASE FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
50	PJC		INSTANTANEOUS OVERCURRENT RELAY
		T&SI	TARGET & SEAL-IN
52/a			AUX. SWITCH ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME OVERCURRENT UNIT
		T&SI	TARGET & SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN UNIT
		T	TARGET
68	CEB		OFFSET MHO BLOCKING RELAY
		MB	OUT-OF-STEP BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUX. FOR OUT-OF-STEP BLOCKING
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUX. TO GD AND G2
		MX	AUX. TO M2
		T	TARGET
85X	NAA		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING AUXILIARY
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
TS			CHANNEL TEST SWITCH

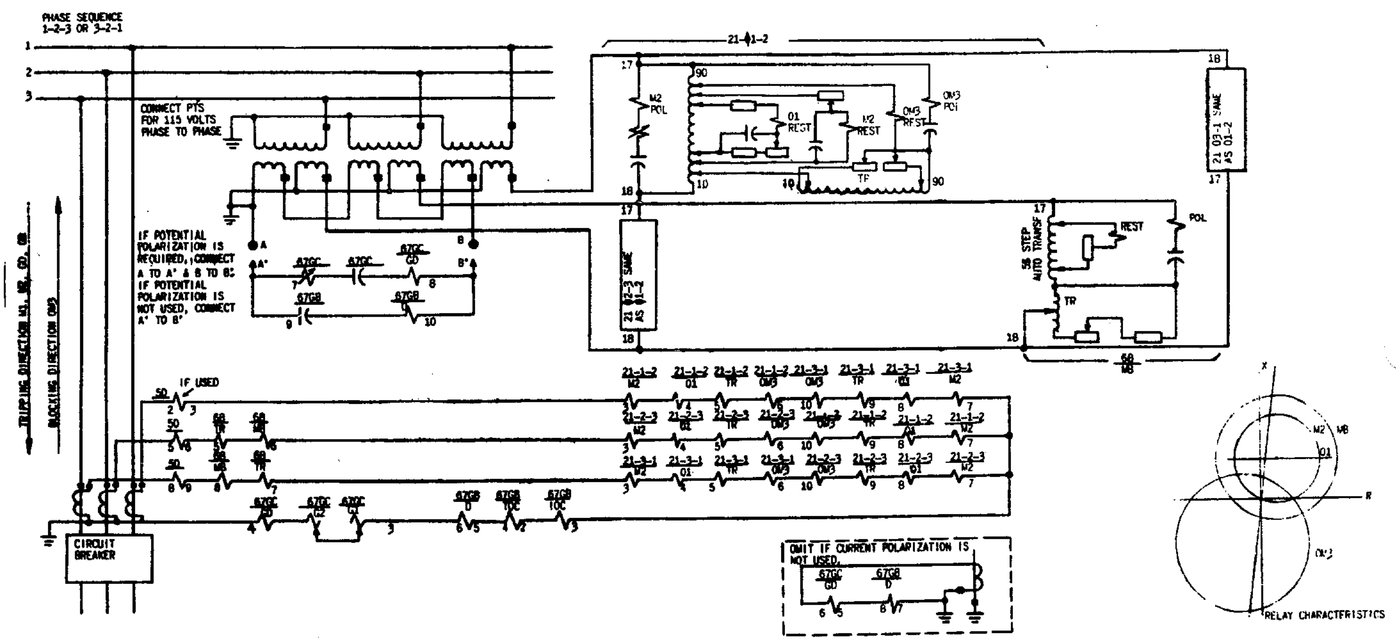
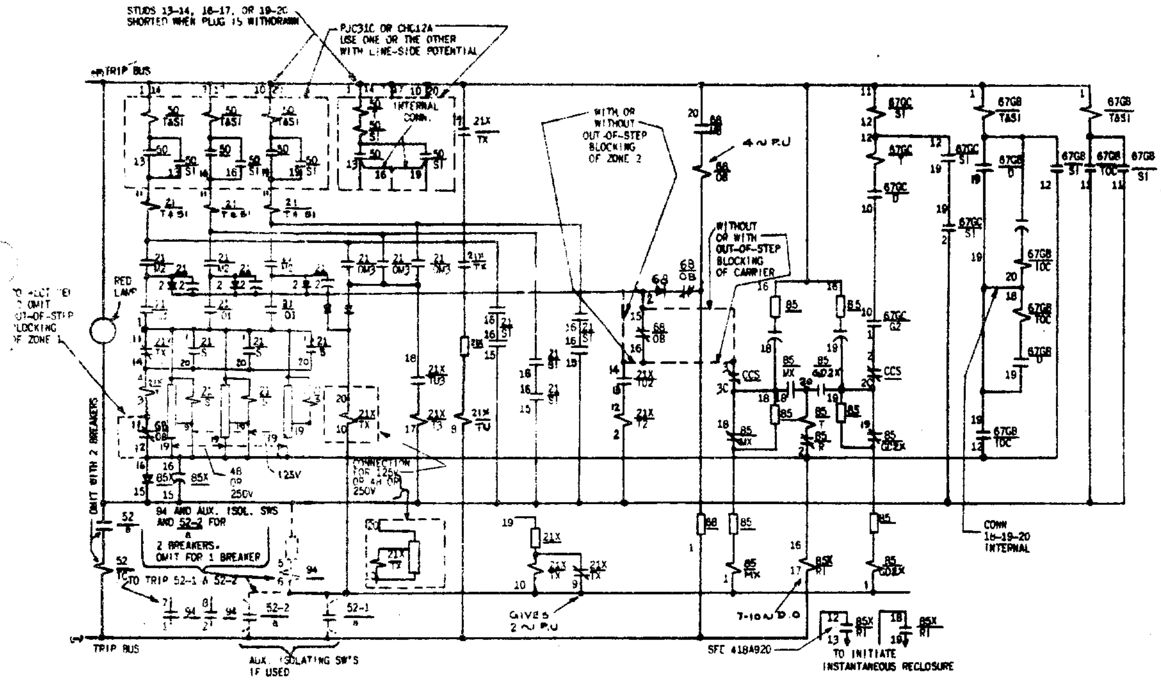


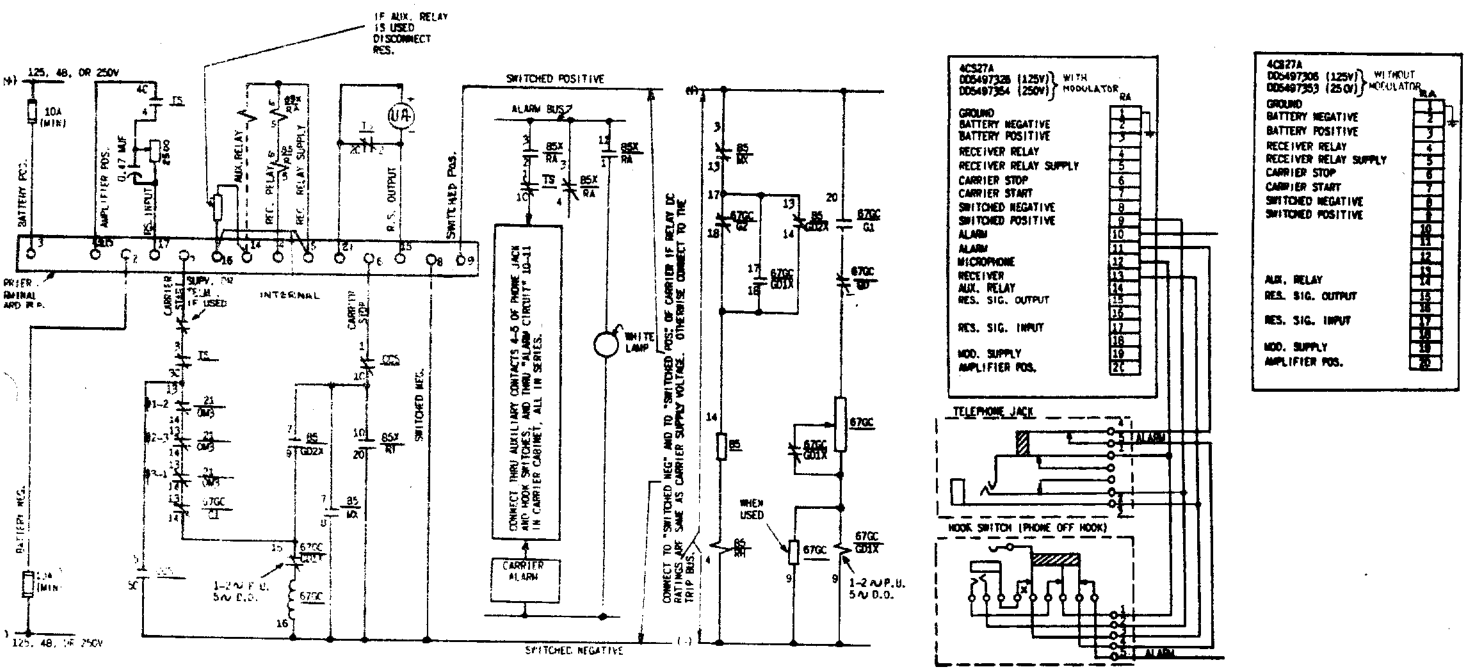
Fig. 14 Overall Elementary Diagram for Carrier-Current Pilot Relayi



CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

TS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC	R.S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					



See Tables VI, XIII and XIV. (7021B83CA Sh.1-2, Sh. 2-3, Sh. 3-1)