Superseded by 41-417B 1 June 1948

Westinghouse

TYPE HZ-3 IMPEDANCE RELAY

INSTRUCTIONS

CAUTION

Before putting protective relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type HZ-3 relay is a three element non-directional, high-speed relay with impedance elements of the balanced-beam type. The relay is used to supplement slow-speed relays on radial circuits. As applied to these circuits, the relay is used for phase fault protection over 80 to 90% of the line section, with the existing slow-speed relays protecting the remaining 20 to 10% and providing back-up protection.

The type HZ-3 relay is also used for phase and ground fault protection of station buses where the impedance of reactors in the feeder circuits connected to the bus is used as a means of discriminating between an internal and external fault.

CONSTRUCTION

The type HZ-3 relay contains three identical instantaneous impedance elements, a contactor switch, and three operation indicators. The elements are constructed as follows:

Impedance Element

Construction details of this element are shown in Figure 1. A balanced beam is pulled downward on the contact end by a current coil and on the other end by two voltage coils. The fluxes of these two potential coils are shifted out of phase with respect to each other to produce a steady pull. A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the element.

A rectangular silver contact is flexibly fastened on the forward end of the beam. As the beam trips, the contact bridges two silver stationary hemispherical contacts mounted on the free end of a short leaf spring. A small set screw determines the position of the leaf spring and provides means for adjusting the contact gap.

Contactor Switch

This is a small solenoid type d-c switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward the disc bridges three silver stationary contacts.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring restrained armature releases the white target which falls by gravity to show the completion of the trip circuit. The high speed action of the indicator is obtained by fastening a weight through a leaf spring to the armature. The added inertia causes the armature to continue its motion after the coil has been short-circuited. The indicator is reset from outside the case by a push rod.

OPERATION

The relay measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it. The relay is connected to receive a current and voltage proportional to those existing on the high-tension line. With a fault in the zone of the relay, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, the voltage at the relay must be equal to the drop in the line due to the current, I, or equal to IZ where Z is the impedance to neutral of the line from the relay to the point of fault. The ratio of the two values is $IZ/I = Z$ Thus, the ratio is constant for any value of current as the voltage on the relay is equal to the current times the line impedance. Therefore, if the impedance element is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at 80 to 90% of the line section, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs beyond this balance point, the beam will not trip as the voltage pull is the greater because of a larger amount of impedance and correspondingly larger potential restraint than for which the beam is balanced.

The trip circuit consists of the three impedance element contacts and the three operation indicator coils in parallel, and this combination in series with the contactor switch coil. When the relay contacts close, the coil is energized and its contacts short around the relay contacts, relieving them of the duty of carrying the breaker tripping current. These contacts remain closed until the trip circuit is opened by a breaker auxiliary switch. The operation indicators show a white target to indicate which of the three impedance element con-

A cover operated switch can be supplied with its contacts wired in series with the trip circuit. This switch opens the trip circuit when the cover is removed. This switch can be added to the existing type FT cases at any time.

Testing:-The relays can be tested in service, in the case but with the external circuits isolated or out of the case as follows:

Testing In Service:-The ammeter test plug can be inserted in the current test jaws after opening the knife-blade switch to check the current thru the relay. This plug consists of two conducting strips separated by an insulating strip. The ammeter is connected to these strips by terminal screws and the leads are carried out thru holes in the back of the insulated handle.

Voltages between the potential circuits can be measured conveniently by clamping #2 clip leads on the projecting clip lead lug on the contact jaw.

Testing In Case:-With all blades in the full open position, the ten circuit test plug can be inserted in the contact jaws. This connects the relay elements to a set of binding posts and completely isolates the relay circuits from the external connections by means of an insulating barrier on the plug. The external test circuits are connected to these binding posts. The plug is inserted in the bottom test jaws with the binding posts up and in the top test switch jaws with the binding posts down.

The external test circuits may be made to the relay elements by #2 test clip leads instead of the test plug. When connecting an external test circuit to the current elements using clip leads, care should be taken to see that the current test jack jaws are open so that the relay is completely isolated from the external circuits. Suggested means for isolating this circuit are outlined above, under "Electrical Circuits".

Testing Out of Case:-With the chassis removed from the base, relay elements may be tested by using the ten-circuit test plug or by #2 test clip leads as described above. The factory calibration is made with the chassis in the case and removing the chassis from the case will change the calibration values by a small percentage . It is recommended that the relay be checked in position as a final check on the calibration.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

CONNECTIONS

Impedance Element

The impedance to the balance point is measured from the point where the potential transformers are connected.

In some applications a power transformer bank forms part of the transmission line, and potential transformers are available only on the bus side of the bank. In this case the relays may be set thru the bank to protect the line only if the bank impedance is not too large as compared with the line impedance. If the bank impedance is too large in comparison with the line impedance, the 80 or 90% setting of the impedance element may cover only a very small percentage of the transmission line or in some cases not cover any of the line section. In order to use the potential transformers on the bus side of the bank under this condition, Type KX compensators are used and the impedance measured from the line side of the bank to the balance point. The type KX compensators (I.L. 41-540) operate from the current transformers and provide voltage compensation equivalent to the drop in the power bank.

The above discussion assumes that power is fed thru the bank to faults on the line. Where a power transformer connects to a high tension transmission line and does not supply power to a line fault, low-tension potential transformers may be used without compensation. Then, the impedance to the balance point is measured from the point where the potential transformers connect to the protected line.

The conventional star connection of current transformers is not as satisfactory as the delta connection where accurate distance relay protection is desired. With this connection, the balance point of the impedance element shifts about 15% depending upon whether a phase-to-phase, a three phase or a double ground fault is involved. That is, if the balance point were adjusted at 80% for a three phase fault, then for a double ground fault the shift may be more or less than plus or minus 15% of the 80% setting, depending upon the relative magnitudes of the positive, negative and zero sequence impedance of the system from the source of power to the fault. This error can be entirely eliminated by making use of the vector difference between the line currents, (i.e. delta currents) for actuating the relay.

The most common method is to connect the main current transformers in star and use a set of auxiliary 5/5 ratio transformers to supply delta currents to impedance element, as shown in Figures 10 and 11. These auxiliary transformers need not be of very large volt-ampere capacity, as they supply only the impedance element coils which are of very low burden.

Trip Circuit

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 4 or 5 amperes in order to reduce the time of the operation of the switch to a minimum and provide more positive operation. If the relay is used to trip an auxiliary multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 3.8 ohms, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used.

The main contacts on the impedance elements will safely close 30 amperes at 250 volts d-c, and the switch contacts will safely carry this current long enough to trip the breaker.

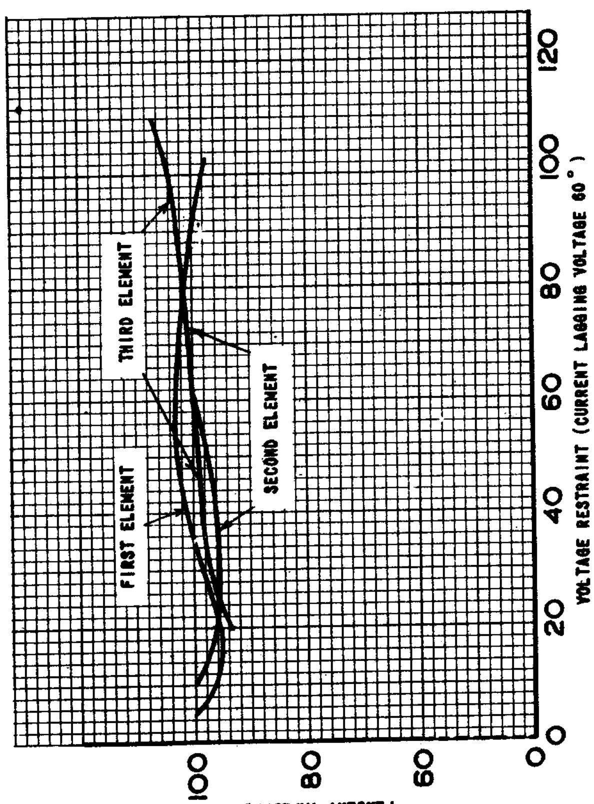

Figure 4
Typical Impedance Curves for all Three Elements.

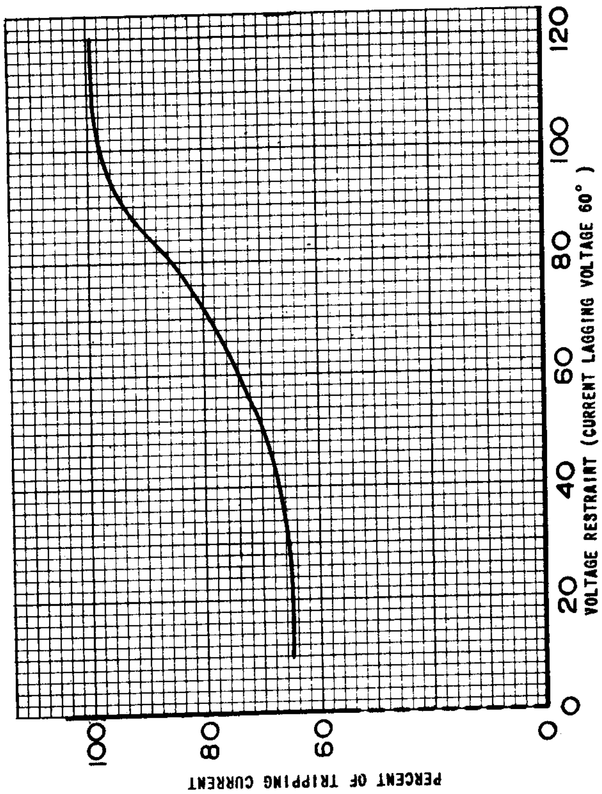

Figure 5
Typical Reset Curves for the First Element.

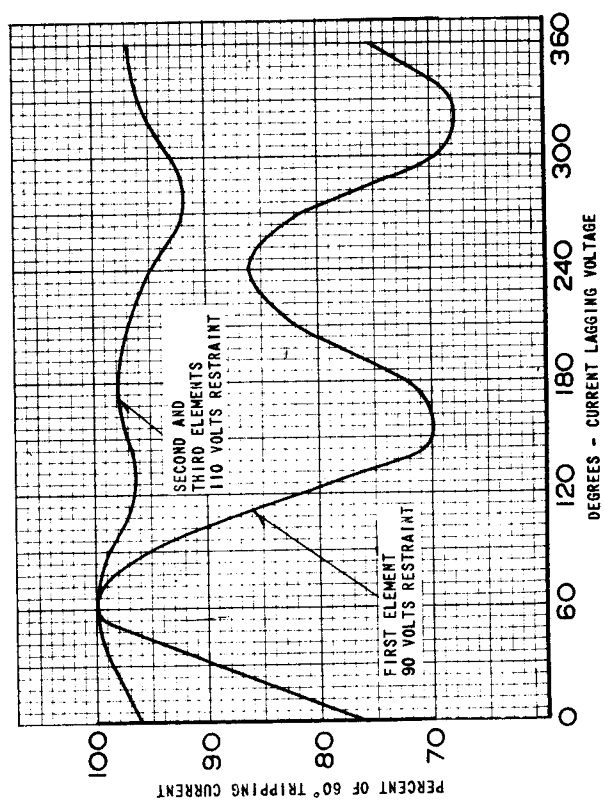

Figure 6
Typical Phase Angle Curves for all Three Elements.

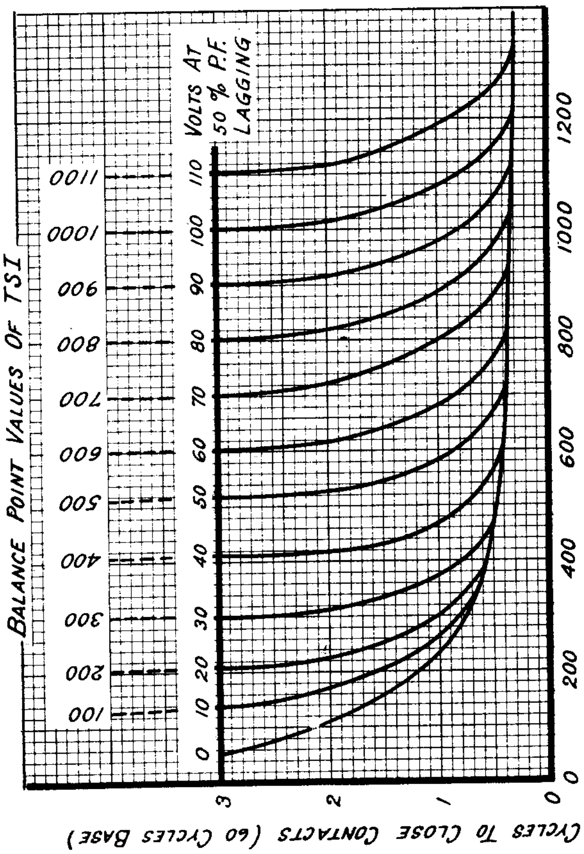

Figure 7
Typical Time of Operation Curves for the First Element.

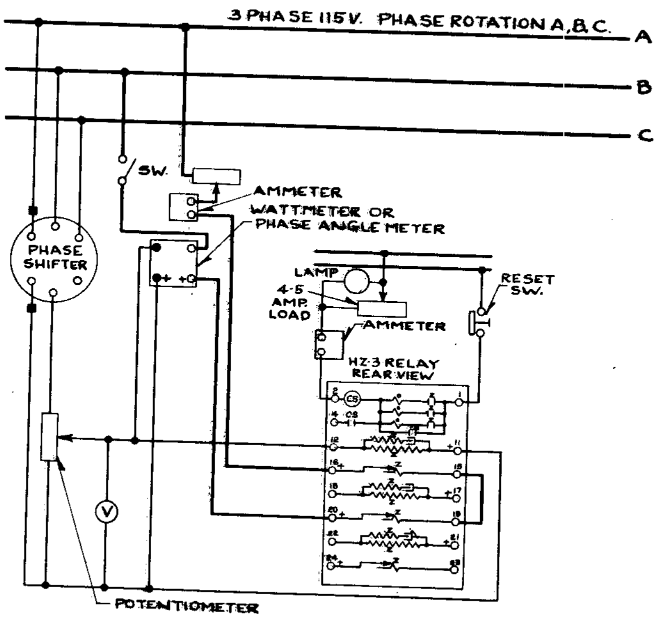

Figure 8
Diagram of Test Connections for the Type HZ-3 Relay in the Standard Case.

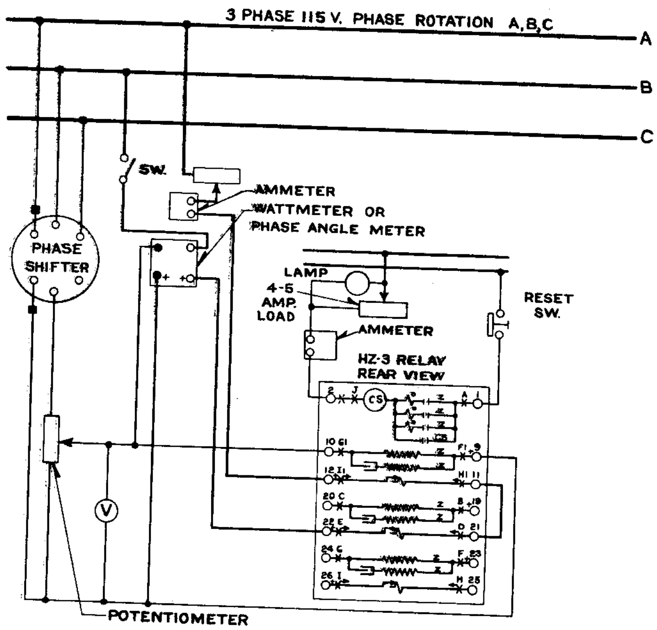

Figure 9
Diagram of Test Connections for the Type HZ-3 Relay in the Type FT Case.

ADJUSTMENT AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be periodically cleaned with a fine file. S#1002110 file is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Impedance Elements

Refer to Figure 1. Adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the beam and the voltage iron circuit. With the beam in the reset position, i.e., with the stop screw against the stop, adjust the vertical gap for .009 inch between the adjustable iron and the beam. Care should be taken in this adjustment to keep the gap the same on both sides. Also, with the beam in the same position adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inch. The above values for the air gaps may be obtained by means of feeler gauges. It should be borne in mind, however, that the values given represent normal, or average values.

The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram. With any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint. In calibrating the first element, the same current should be passed thru the second element in the reverse direction thus simulating a phase-to-phase fault. In this way the small amount of electrical interference between elements is calibrated out. Similarly, the third element current coil should be energized in the reverse direction when calibrating the second element, and the first element current coil should be energized in the reverse direction when calibrating the third element. In the factory adjustment, this is done at T = 20.8 and S = 1.4 for the 0.6 to 6.0 ohm relay, and at T = 13, S = 1.6 for the 0.2 to 2.0 ohm relay.

The stationary contacts should be adjusted to give .015 inch clearance between them and the silver bridge on the beam when the beam is in the reset position. The bridge should be made to touch both contacts simultaneously, and deflect the contact springs at least .010 inch before the beam strikes the bronze stop on the core screw.

It is difficult to adjust accurately the contacts by eye A good method consists in first adjusting one of the contacts to the correct gap and then applying just sufficient current to trip the beam against a restraint of about 5 volts. While the beam is in this position, that is, lightly pressing on the one contact, the other contact should be slowly adjusted upward by means of the set screw until it just touches the silver bridge without lifting it off the other contact. The trip circuit should be energized so that the lighting of a lamp or the tripping of an auxiliary relay will show when both contacts are made.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64" when the switch is picked up. This can be done by turning the relay up-side-down or by disconnecting the switch and turning it up-side-down. Then screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32" by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passed through the coil.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed thru the coil. Adjustments may be made by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. Also, the amount of over-hang of the armature on the latch may be adjusted by means of the small screw bearing on the flat spring carrying the inertia weight. The best adjustment will usually be found when this screw just touches the flat spring with the armature in the reset position. If the two helical springs which reset the armature are replaced with new springs, they should be weakened slightly by stretching just beyond their elastic limit.

Calibration of Impedance Elements

The current required to operate the impedance elements against any given voltage is obtained from the equation:

$$TS = \frac{10\ E}{I} \qquad (3)$$

where T is the current tap and S is the setting of the calibrated core screw, E and I are the voltage and current respectively applied to the relay. Thus, if the setting is T = 20.8, S =1.4 and the voltage is 35 volts, then the current required at 60° lagging is:

$$I = \frac{10\ E}{TS} = \frac{10 \times 35}{20.8 \times 1.4} = 12 \text{ amperes}$$

When checking the calibration, it is essential that the polarity as shown in the internal schematics be used, otherwise an error will be introduced.

The variation of tripping current for a given voltage as the phase angle between current and voltage is varied is shown in Figure 5. To make sure that the relay is operating at 60° lag and not 240°, the current leads can be reversed and the beam should operate on a smaller current if the connections were originally correct.

The general shape of the impedance curve for different ohm settings is shown in Figure 4. These curves are obtained by tripping the beam against different voltages for a constant T and S setting and then plotting the ratio E/I in percent of the 35 volt calibrating impedance against the voltage. The lower voltage points (5 to 15 volts) are considerably affected by the mechanical balance of the beam, while the higher points are but little influenced.

Accurate time tests on the instantaneoue element can only be taken with the aid of an oscillograph or high-speed timer. The time of operation in cycles (60 cycle per second basis) of the impedance element for various balance points is given in Figure 7. By using these curves the operating speed can be determined for any value of the current or voltage applied to the element.

Caution

Make certain that the stops on the rear and front of the beam are absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

Also, when checking the impedance element at low voltage, observe the tripping of the beam instead of an indication in the trip circuit. This will prevent an error in the contact adjustment which might otherwise affect the beam calibration.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The 60 cycle burden of the various circuits of this relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	V.A.	P.F. Angle
Impedance Element (each)	2.0	20° lag

CURRENT CIRCUITS

Circuit	Tap	Amps	V.A.	P.F. Angle
Impedance Element	45	8.66	6	42°
	13.5	8.66	1.3	22°
Auxiliary Star-Delta C.T. S#869125 See I.L. 41-535	5Y/8.66 Δ 5		3.5	10°

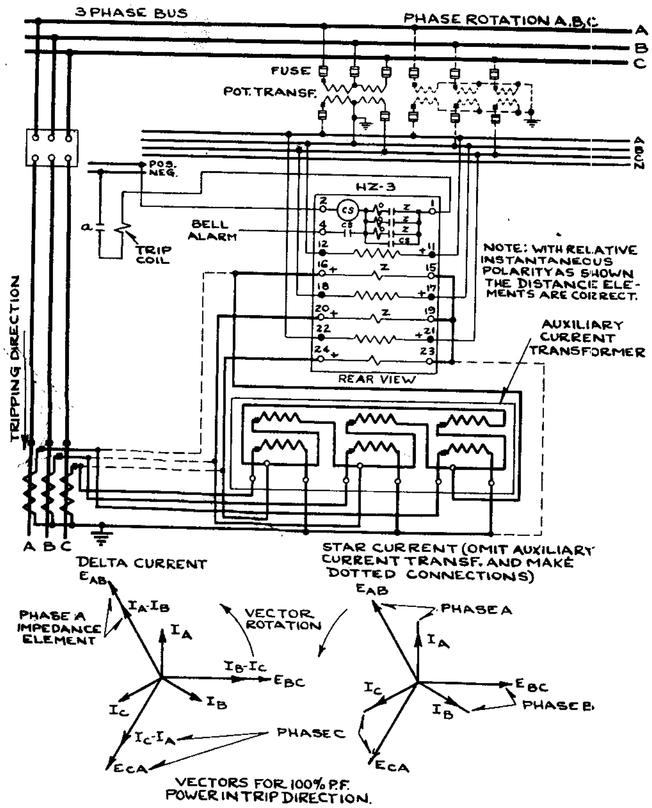

Figure 10
External Connections of the Type HZ-3 Relay in the Standard Case for Phase Fault Protection Using Either Star or Delta Current in all Elements.

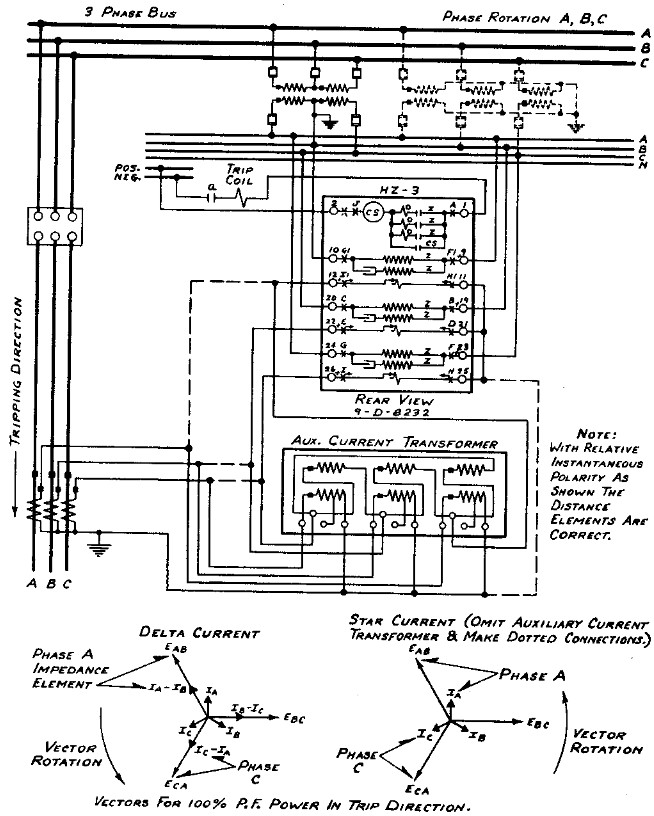

Figure 11
External Connections of the Type HZ-3 Relay in the Type FT Case for Phase Fault Protection Using Either Star or Delta Current in all Elements.

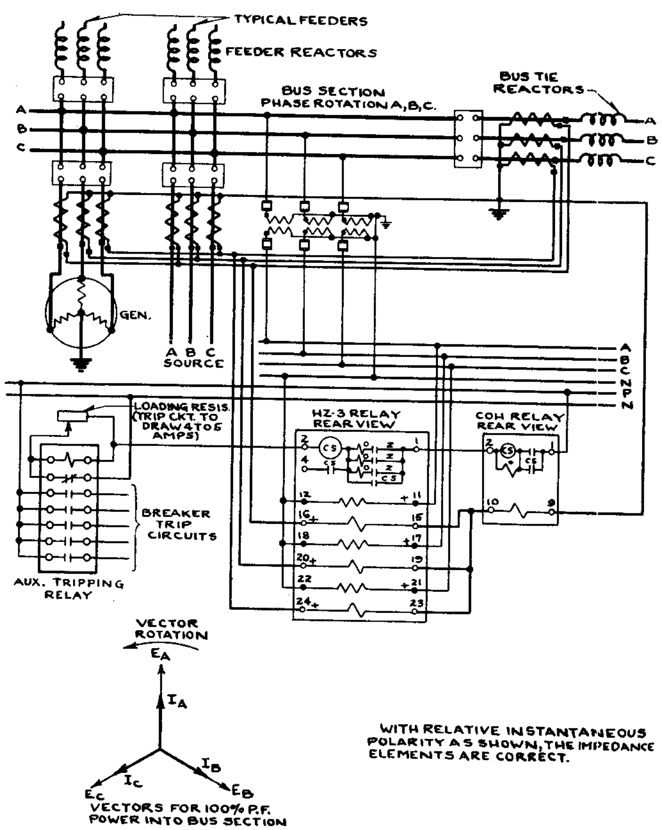

Figure 12
External Connections of the Type HZ-3 Relay in the Standard Case for Phase-to-Ground Fault Protection on a Bus Section with Feeder Reactors.

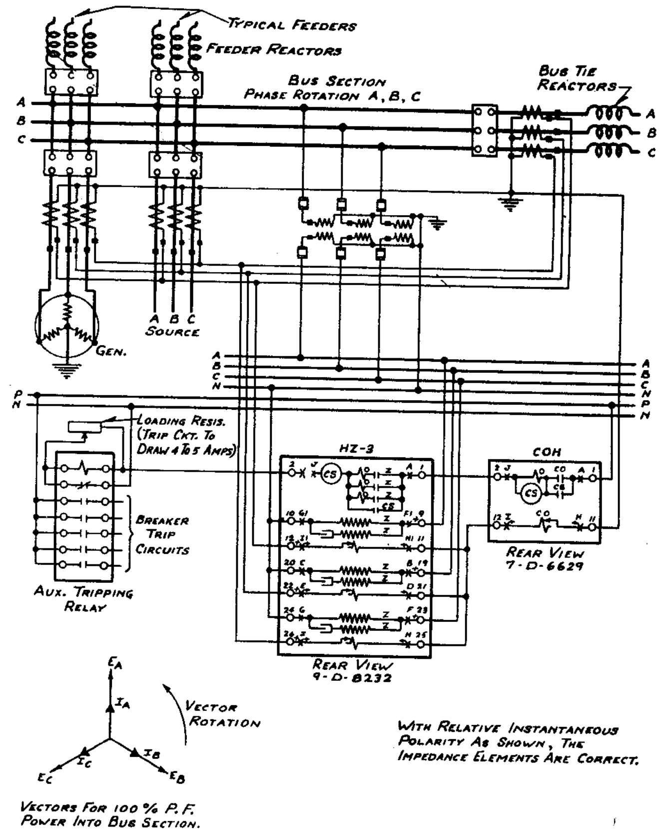

Figure 13
External Connections of the Type HZ-3 Relay in the Type FT Case for Phase-to-Ground Fault Protection on a Bus Section with Feeder Reactors.

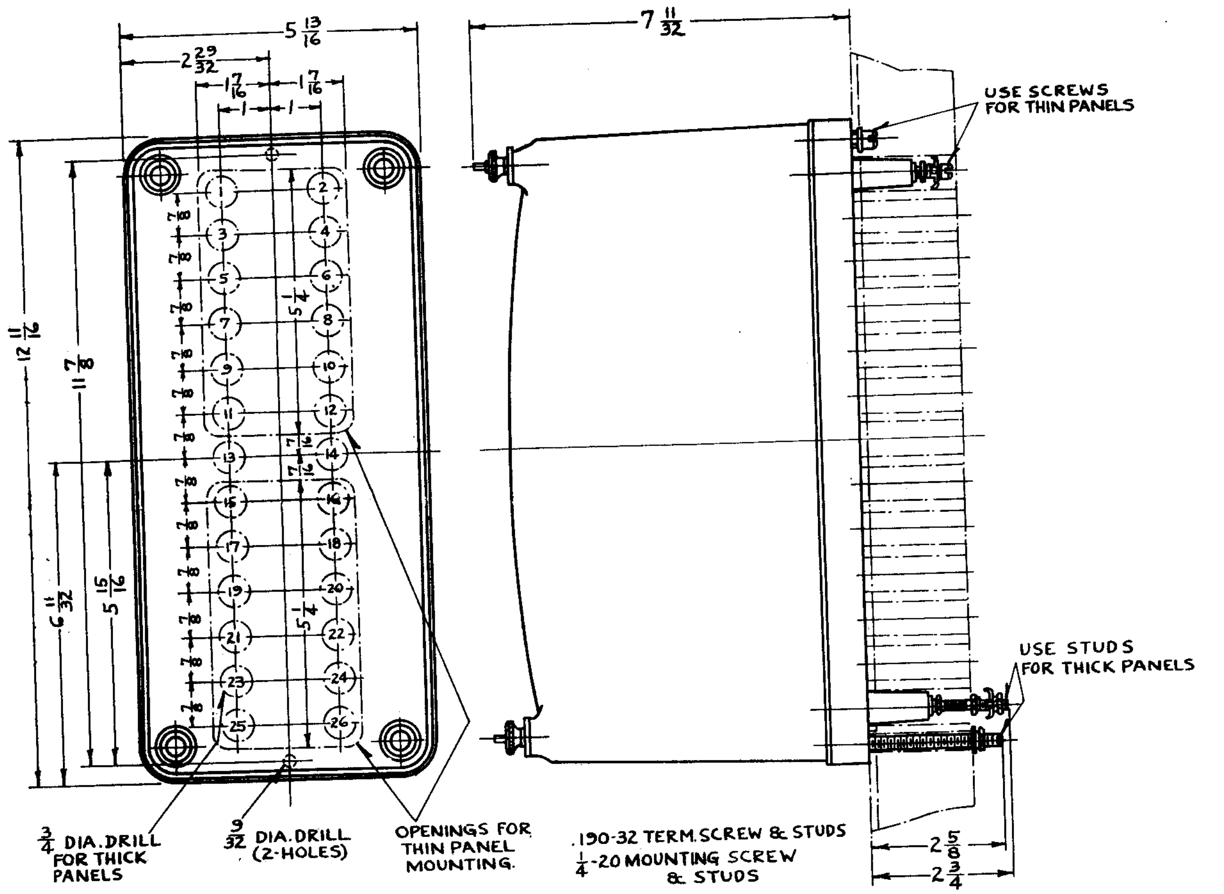

Figure 14
Outline and Drilling Plan of the Standard Projection Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

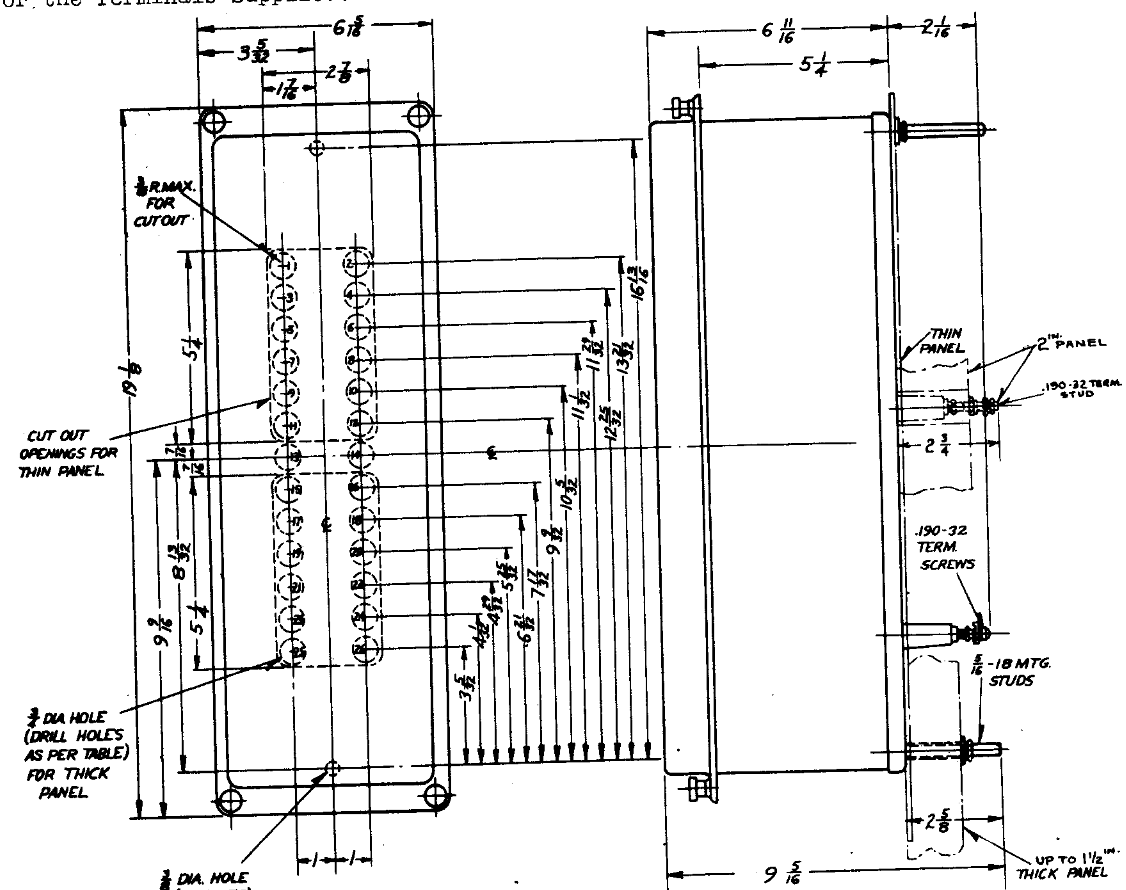

Figure 15
Outline and Drilling Plan of the M20 Projection Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

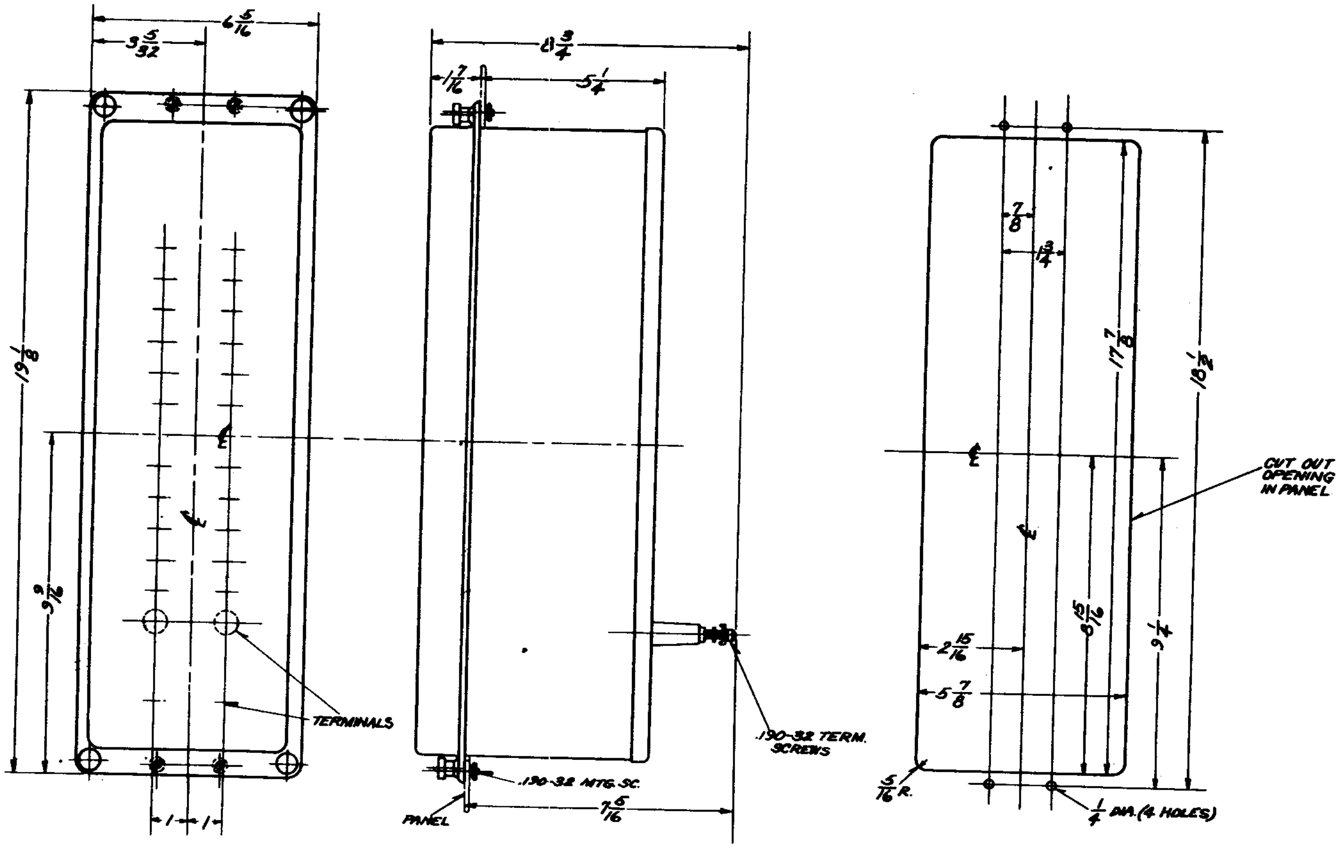

Figure 16
Outline and Drilling Plan of the M20 Semi-Flush Type FT Flexitest Case. For Reference Only.

WESTINGHOUSE ELECTRIC CORPORATION
Meter Division, Newark, N. J.

10-45

Westinghouse

TYPE HZ-3 IMPEDANCE RELAY

INSTRUCTIONS

CAUTION

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APPLICATION

The type HZ-3 relay is a three element non-directional, high-speed relay with impedance elements of the balanced-beam type. The relay is used to supplement slow-speed relays on radial circuits. As applied to these circuits, the relay is used for phase fault protection over 80 to 90% of the line section, with the existing slow-speed relays protecting the remaining 20 to 10% and providing back-up protection.

The HZ-3 relay is also used for phase and ground fault protection of station buses where the impedance of reactors in the feeder circuits connected to the bus is used as a means of discriminating between an internal and external fault.

CONSTRUCTION

The type HZ-3 relay contains three identical instantaneous impedance elements, a contactor switch, and an operation indicator mounted in the standard cases of figure 10 and 11. The elements are constructed as follows:

Impedance Element

Construction details of this element are shown in figure 1. A balanced beam is pulled downward on the contact end by a current coil and on the other end by two voltage coils. The fluxes of these two potential coils are shifted out of phase with respect to each other to produce a steady pull so that practically a constant balance can be obtained regardless of the phase angle between the current and voltage coil fluxes. A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the element.

A rectangular silver contact is flexibly fastened on the forward end of the beam. As the beam trips, the contact bridges two silver stationary hemispherical contacts mounted on the free end of a short leaf spring. A small set screw determines the position of the leaf spring and provides means for adjusting the contact gap.

Contactor Switch

This is a small solenoid type d-c. switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upwards the disc bridges three silver stationary contacts.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring restrained armature releases the white target which falls by gravity to show the completion of the trip circuit. The high speed action of the indicator is obtained by fastening a weight through a leaf spring to the armature. The added inertia causes the armature to continue its motion after the coil has been short-circuited. The indicator is reset from outside the case by a push rod in the cover stud.

OPERATION

The relay measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it. The relay is connected to receive a current and voltage proportional to those existing on the high-tension line. With a fault in the zone of the relay, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, the voltage at the relay must be equal to the drop in the line due to the current, I, or equal to IZ where Z is the impedance to neutral of the line from the relay to the point of fault. The ratio of the two values is $IZ/I = Z$. Thus, the ratio is constant for any value of current as the voltage on the relay is equal to the current times the line impedance. Therefore, if the impedance element is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at 80 to 90% of the line section, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs beyond this balance point, the beam will not trip as the voltage pull is the greater due to a large amount of impedance and correspondingly larger potential restraint than the beam is balanced for.

The trip circuit consists of the three impedance element contacts and the three operation indicator contacts in parallel, and this combination in series with the contactor switch coil. When the relay contacts close, the coil is energized and its contacts short around the relay contacts, relieving them of the duty of carrying the breaker tripping current. These

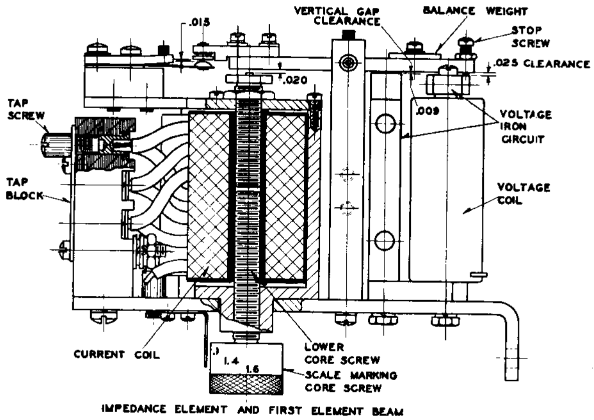


Figure 1
Sectional View of the Impedance Elements.

contacts remain closed until the trip circuit is opened by a breaker auxiliary switch. The third contact of the contactor switch is connected to a separate relay terminal to operate an alarm circuit. The operation indicators show a white target to indicate which of the three impedance element contacts close to complete the trip circuit.

CHARACTERISTICS

The relay is available in two impedance ranges: 0.6 to 6.0 ohms and 0.2 to 2.0 ohms. The difference in the two ranges is in the current coils of the impedance element and the corresponding tap markings. The tap and scale markings are as follows:

0.6 to 6.0 Ohm Relay

Taps - 6.2, 9.4, 13.5, 20.8, 29.8, 45

Core Screw Marking - .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4

0.2 to 2.0 Ohm Relay

Taps - 2, 3, 4, 6, 9, 13

Core Screw Marking - .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.6

SETTINGS

The type HZ-3 relay requires a setting for each of the three impedance elements. The following nomenclature will be used:

Z = the line-to-neutral ohmic impedance of the protected line from the relay to the 80 or 90% balance point.
R_c = The current transformer ratio
R_v = The potential transformer ratio
T = The impedance element current tap value
S = The impedance element current core screw value. The values appears as a series of dots on the drum of the lower core screw adjusting knob.

Since the impedance of the voltage circuit of the relay is the same at all times, the balance point of the element is adjusted by changing the pull on the current coil. This is done by taps (T) on the current coil winding, and by the core screw (S) which varies the magnetic air gap for the current flux.

The most satisfactory method of arriving at the tap setting is by the use of the following formulas:

For Impedance Elements Receiving Delta Current Use:

$$TS = \frac{10\ Z\ R_c}{R_v} \quad (1)$$

For Impedance Element Receiving Star Current Use:

$$TS = \frac{17.3\ Z\ R_c}{R_v} \quad (2)$$

The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should be screwed in the desired tap before removing the existing tap screw to prevent open circuiting the current transformers.

The numbers on the core screw appear in ascending order as the core screw is screwed into the core. In some cases, a question of doubt may arise whether the scale setting is correct, or is out by one full turn of the core screw. In such a case, the point may be verified by turning the core screw all the way in. Then back out the core screw until the highest scale marking just comes under the end of the pointer. This will occur in less than 3/4 of a turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

The above formulae are based on the relay being used on a 60° line and is correct for lines of that angle. For lines other than 60° a slight error is introduced which may be as much as 8% and 6% on 40° and 80° lines respectively. However, the formula relay setting can be corrected for lines other than 60° by using the curve of figure 4. The scale reading should be decreased so that the current to trip the beam at the line angle is equal to the current to trip on a 60° line.

The formulae settings are sufficiently accurate for most installations. Where it is desired to set the balance point more accurately the tap and scale values may be checked by applying to the relay the voltage, current, and phase angle conditions which will be impressed on it for a fault at the desired balance point. A slight change in the scale value from that calculated may be required.

As an example of the formula setting, set the impedance elements to protect a 60°, 110 kv., 60 cycle line, 75 miles long. The line-to-neutral impedance is .75 ohms per mile. The current transformer ratio is 400/5, and the potential transformer ratio is 1000/1. Each element is to protect 90% of the line section or for a balance point .90 x 75 x .75 = 50.6 ohms away. Then

$$TS = \frac{10 \times 50.6 \times 80}{1000} = 40.5$$

Set tap = 29.8 and core screw = 1.36 on a 0.6 to 6.0 ohm relay. Since the relay is a three-phase relay, the settings for the second and third elements will be duplicate of the first as above.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs. Either of these studs may be utilized for grounding the metal base. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

CONNECTIONS

Impedance Element

The impedance to the balance point is measured from the point where the potential transformers are connected.

In some applications a power transformer bank forms part of the transmission line, and potential transformers are available only on the bus side of the bank. In this case the relays may be set thru the bank to protect the line only if the bank impedance is not too large as compared with the line impedance. If the bank impedance is too large in comparison with the line impedance, the 80 or 90% setting of the impedance element may cover only a very small percentage of the transmission line or in some cases not cover any of the line section. In order to use the potential transformers on the bus side of the bank under this condition, Type KX compensators are used and the impedance measured from the line side of the bank to the balance point. The type KX compensators operate from the current transformers and provide voltage compensation equivalent to the drop in the power bank.

The above discussion assumes that power is fed thru the bank to faults on the line. Where a power transformer connects to a high tension transmission line and does not supply power to a line fault, low-tension potential transformers may be used without compensation. Then, the impedance to the balance point is measured from the point where the potential transformer connect to the protected line.

The conventional star connection of current transformer is not as satisfactory as the delta connections where accurate distance relay protection is desired. With this connection the balance point of the impedance element shifts about 15% depending upon whether a phase-to-phase, a three phase or a double ground fault is involved. That is, if the balance point were adjusted at 80% for a three phase fault, then for a double ground fault the shift may be more or less than plus or minus 15% of the 80% setting, depending upon the relative magnitudes of the positive, negative and zero sequence impedance of the system from the source of power to the fault. This error can be entirely eliminated by making use of the vector difference between the line currents, (i.e. delta currents) for actuating the relay.

The most common method is to connect the main current transformers in star and use a set of auxiliary 5/5 ratio transformers to supply delta currents to impedance element, as shown in figure 8. These auxiliary transformers need not be of very large volt-ampere capacity, as they supply only the impedance coils which are of very low burden.

Trip Circuit

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 4 or 5 amperes in order to reduce the time of the operation of the switch to a minimum and provide more positive operation. If the relay is used to trip an auxiliary

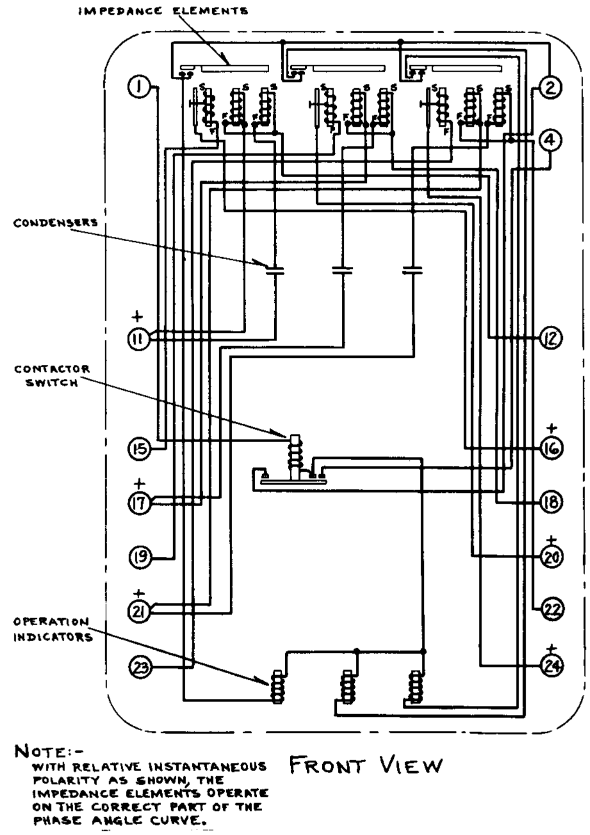


Figure 2
Internal Wiring Diagram of the Type HZ-3 Relay.

multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 3.8 ohms, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used.

The main contacts on the impedance elements will safely close 30 amperes at 250 volts d-c., and the switch contacts will safely carry this current long enough to trip the breaker.

ADJUSTMENT & MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed or the relay taken apart for repairs, the following instructions should be followed in reassembling and setting it.

All contacts should be periodically cleaned with a fine file. S#1002110 file is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Impedance Elements

Refer to figure 1. Adjust the stop screw on the rear of the beam to give a clearance of .025 inches between the beam and the voltage iron circuit. With the beam in the reset position, i.e., with the stop screw against the stop, adjust the vertical gap for .009 inches between the adjustable iron and the beam.

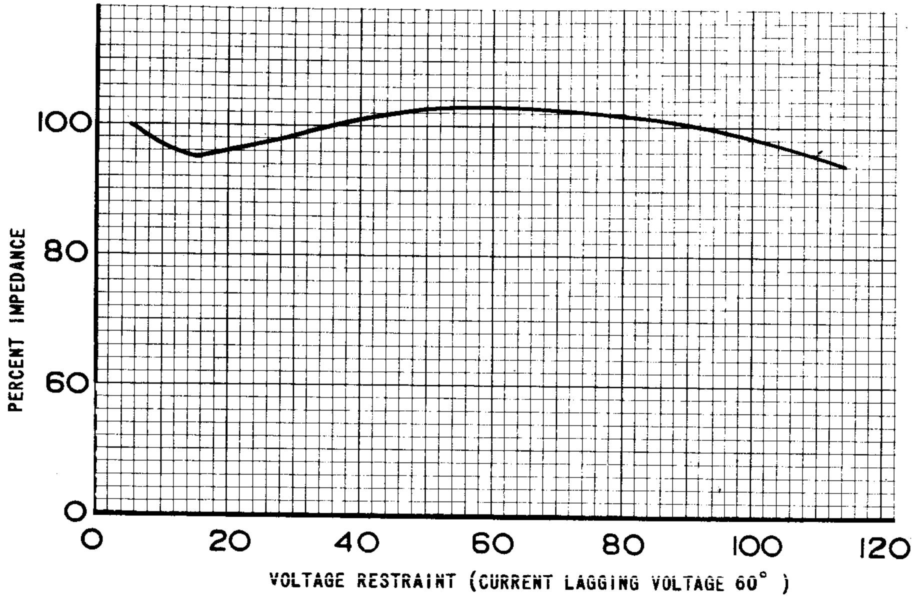


Figure 3
Typical Impedance Curve for the Impedance Elements.

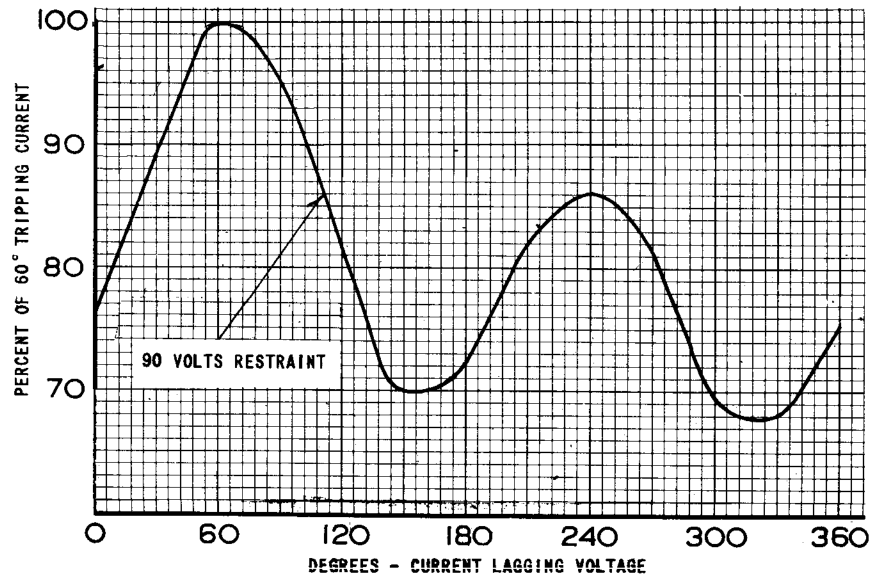


Figure 4
Typical Phase Angle Curve of the Impedance Elements.

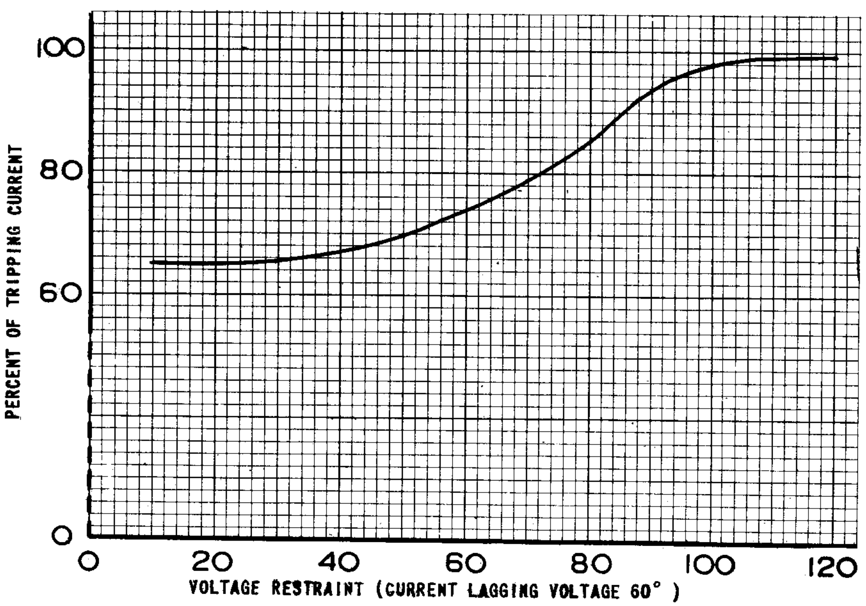


Figure 5
Typical Reset Curve for the Impedance Elements.

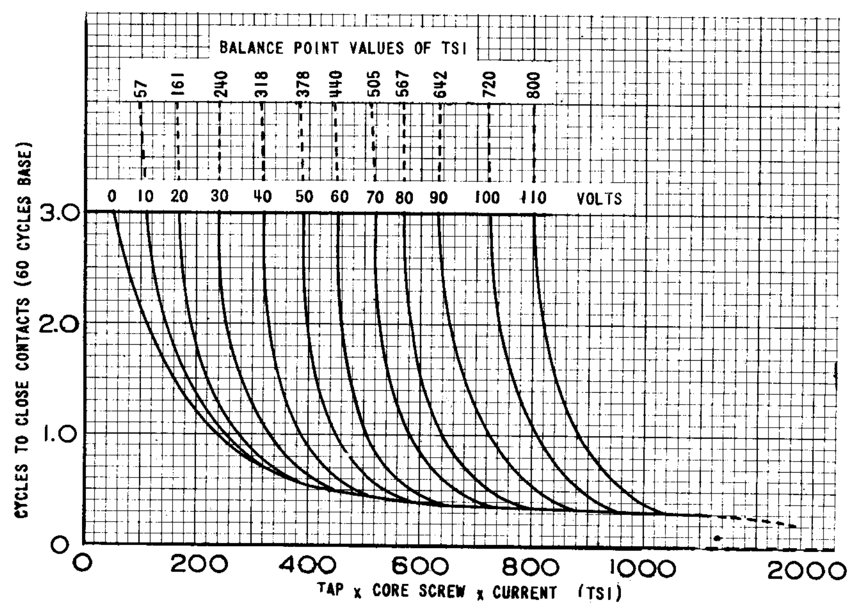


Figure 6
Typical Time of Operation Curves for the Impedance Elements.

Care should be taken in this adjustment to keep the gap the same on both sides. Also, with the beam in the same position adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inches. The above values for the air gaps may be obtained by means of feeler gauges. It should be borne in mind, however, that the values given represent normal, or average values.

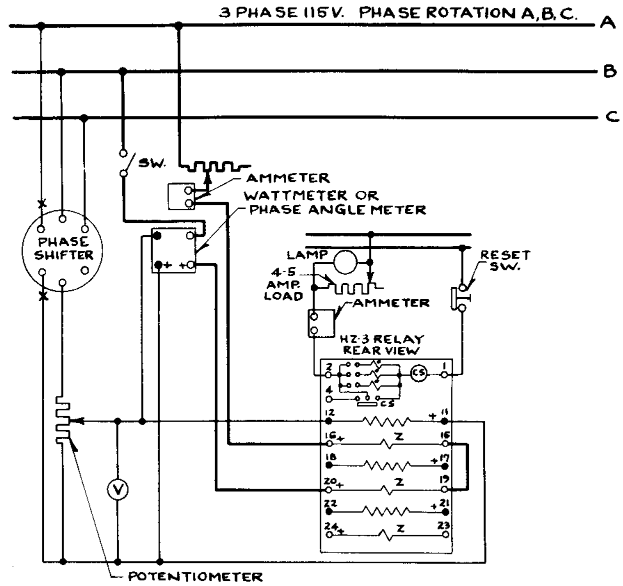
The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram, figure 7. With any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint. In calibrating the first element, the same current should be passed thru the second element in the reverse direction thus simulating a phase-to-phase fault. In this way the small amount of electrical interference between elements is calibrated out. Similarly, the third element current coil should be energized in the reverse direction when calibrating the second element, and the first element current coil should be energized in the reverse direction when calibrating the third element. In the factory adjustment, this is done at T = 20.8 and S = 1.14 for the 0.6 to 6.0 ohm relay, and at T = 13, S = 1.6 for the 0.2 to 2.0 ohm relay.

The stationary contacts should be adjusted to give .015 inches clearance between them and the silver bridge on the beam when the beam is in the reset position. The bridge should be made to touch both contacts simultaneously, and deflect the contact springs at least .010 inches before the beam strikes the bronze stop on the core screw.

It is difficult to accurately adjust the contacts by eye. A good method consists in first adjusting one of the contacts to the correct gap and then applying just sufficient current to trip the beam against a restraint of about 5 volts. While the beam is in this position, that is, lightly pressing on the one contact, the other contact should be slowly adjusted upward by means of the set screw until it just touches the silver bridge without lifting it off the other contact. The trip circuit should be energized so that the lighting of a lamp or the tripping of an auxiliary relay will show when both contacts are made.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64" when the switch is picked up. This can be done by turning the relay up-side-down or by disconnecting the switch and turning it up-side-down. Then screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32" by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test



CONNECTIONS SHOWN FOR TEST OF FIRST ELEMENT ONLY.

Figure 7
Diagram of Test Connections.

for sticking after 30 amperes d-c. have been passed through the coil.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c. gradually applied. Test for sticking after 30 amperes d-c. is passed thru the coil. Adjustments may be made by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. Also, the amount of over-hang of the armature on the latch may be adjusted by means of the small screw bearing on the flat spring carrying the inertia weight. The best adjustment will usually be found when this screw just touches the flat spring with the armature in the reset position. If the two helical springs which reset the armature are replaced with new springs, they should be weakened slightly by stretching just beyond their elastic limit.

Calibration of Impedance Elements

The current required to operate the impedance elements against any given voltage is obtained from the equation:

$$TS = \frac{10\,E}{I} \qquad (3)$$

where T is the current tap and S is the Setting of the calibrated core screw, E and I are the voltage and current respectively applied to the relay. Thus, if the setting is T = 20.8, S = 1.4 and the voltage is 35 volts, then the current required at 60° lagging is:

$$I = \frac{10\,E}{TS} \qquad I = \frac{10 \times 35}{20.8 \times 1.4} = 12 \text{ amperes}$$

When checking the calibration, it is essential that the polarity be as given in figure 7, otherwise an error will be introduced.

Figure 4 shows the variation of tripping current for a given voltage as the phase angle between current and voltage is varied. To make sure that the relay is operating at 60° lag and not 240°, the current leads can be reversed and the beam should operate on a smaller current if the connections were originally correct.

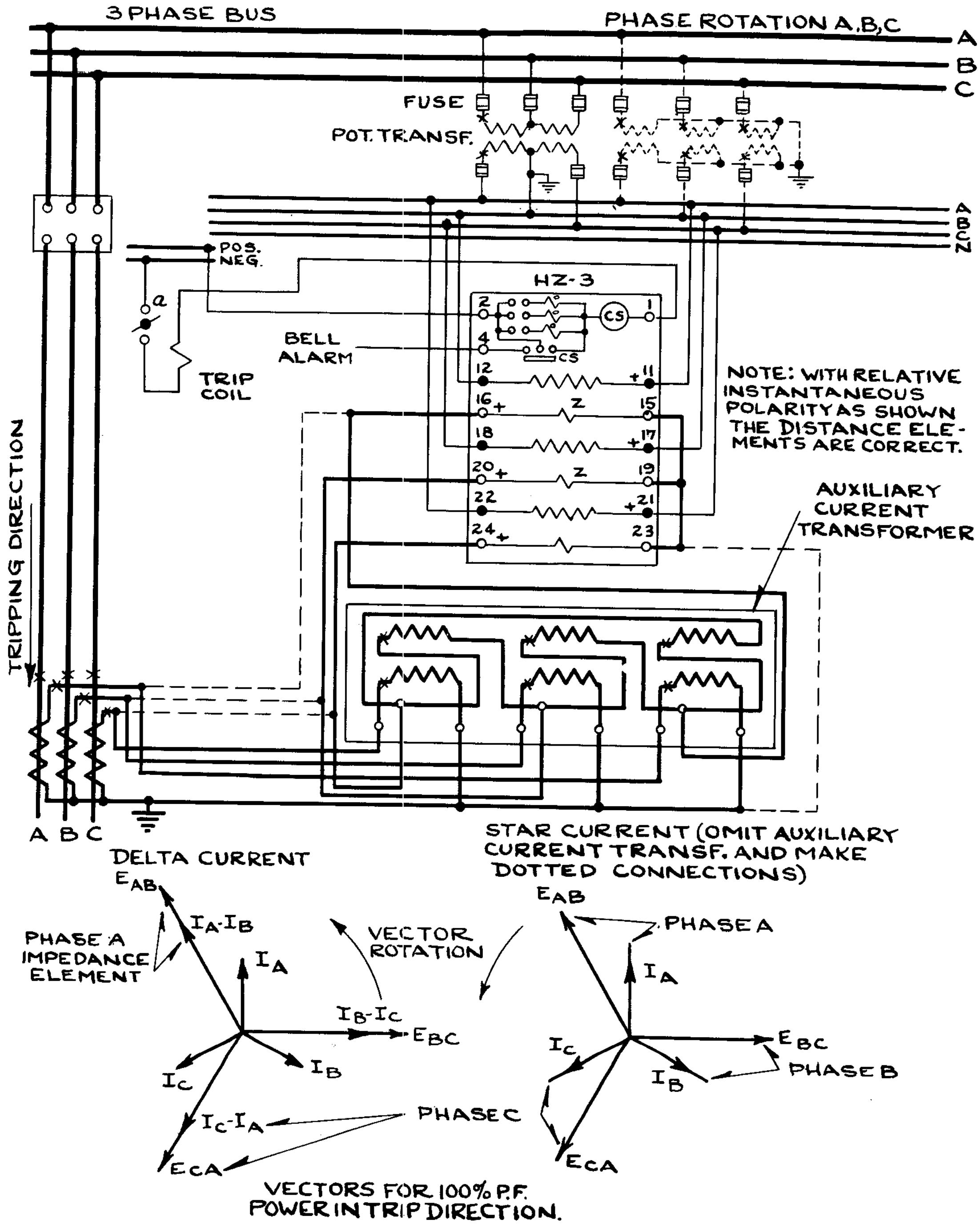


Figure 8
External Connections for Phase Fault Protection Using Star Current or Delta Current on All Elements as Required.

Figure 3 shows the general shape of the impedance curve for different ohm settings. These curves are obtained by tripping the beam against different voltages for a constant T and S setting and then plotting the ratio E/I in per cent of the 35 volt calibrating impedance against the voltage. The lower voltage points (5 to 15 volts) are considerably affected by the mechanical balance of the beam, while the higher points are but little influenced.

Accurate time tests on the instantaneous element can only be taken with the aid of an oscillograph or high-speed timer. Figure 6 shows the time of operation in cycles (60 cycle per second basis) of the impedance element for various balance points. By using these curves the operating speed can be determined for any value of the current or voltage applied to the element.

Caution

Make certain that the stops on the rear and front of the beam are absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

Also, when checking the impedance element at low voltage, observe the tripping of the beam instead of an indication in the trip cir-

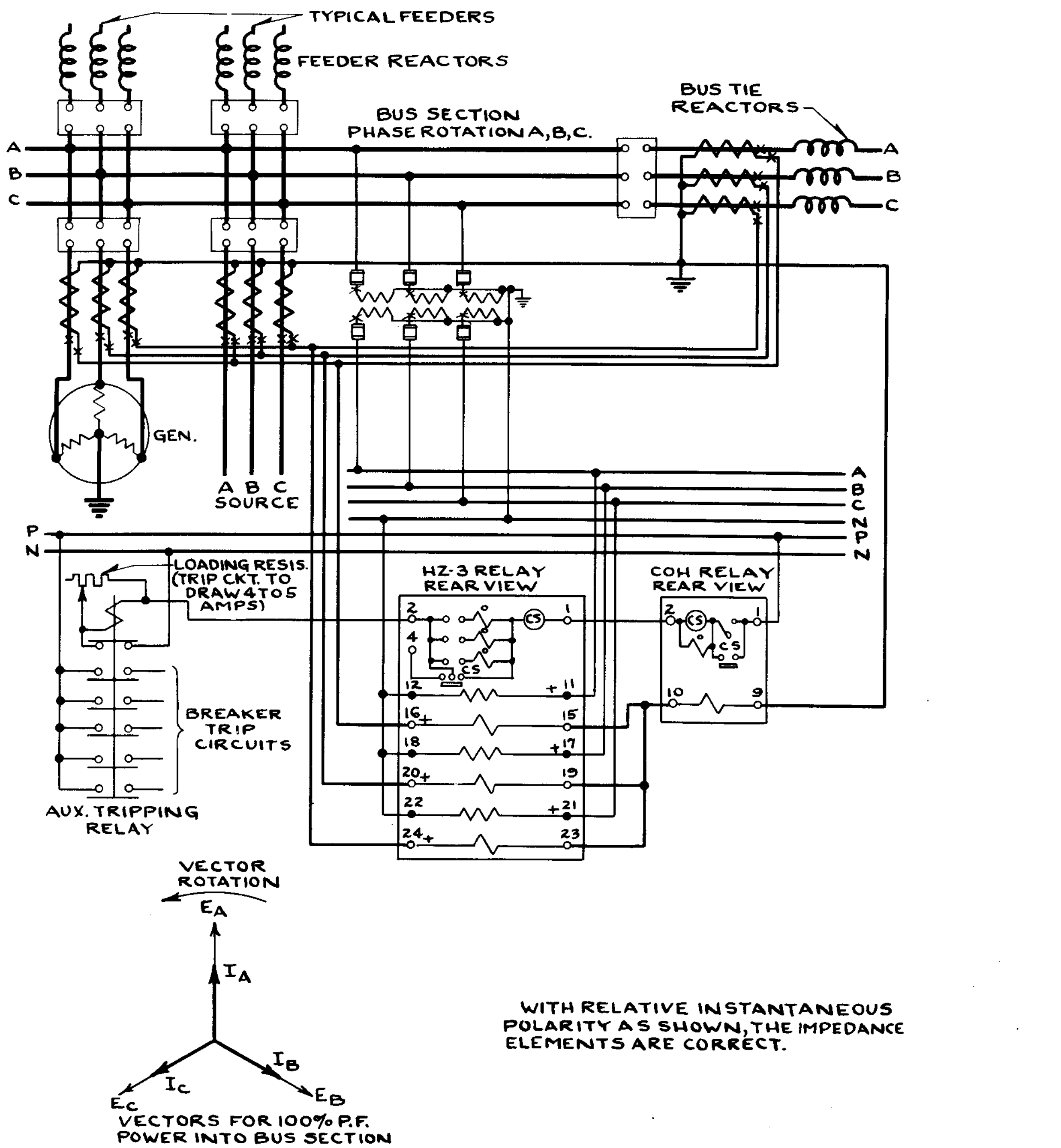


Figure 9
External Connections for Phase to Ground Fault Protection on a Bus Section with Feeder Reactors.

cuit. This will prevent an error in the contact adjustment which might otherwise affect the beam calibration.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The 60 cycle burden of the various circuits of this relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	V.A.	P.F. Angle
Impedance Element (each)	2.0	20° lag

CURRENT CIRCUITS

Circuit	Tap	Amps.	V.A.	P.F.Angle
Impedance Element	45	8.66	6	42°
	13.5	8.66	1.3	22°
Auxiliary Star-Delta C.T. S#879127 See I.L. 2632-A Newark Works.	5Y/8.66Δ5		3.5	10°

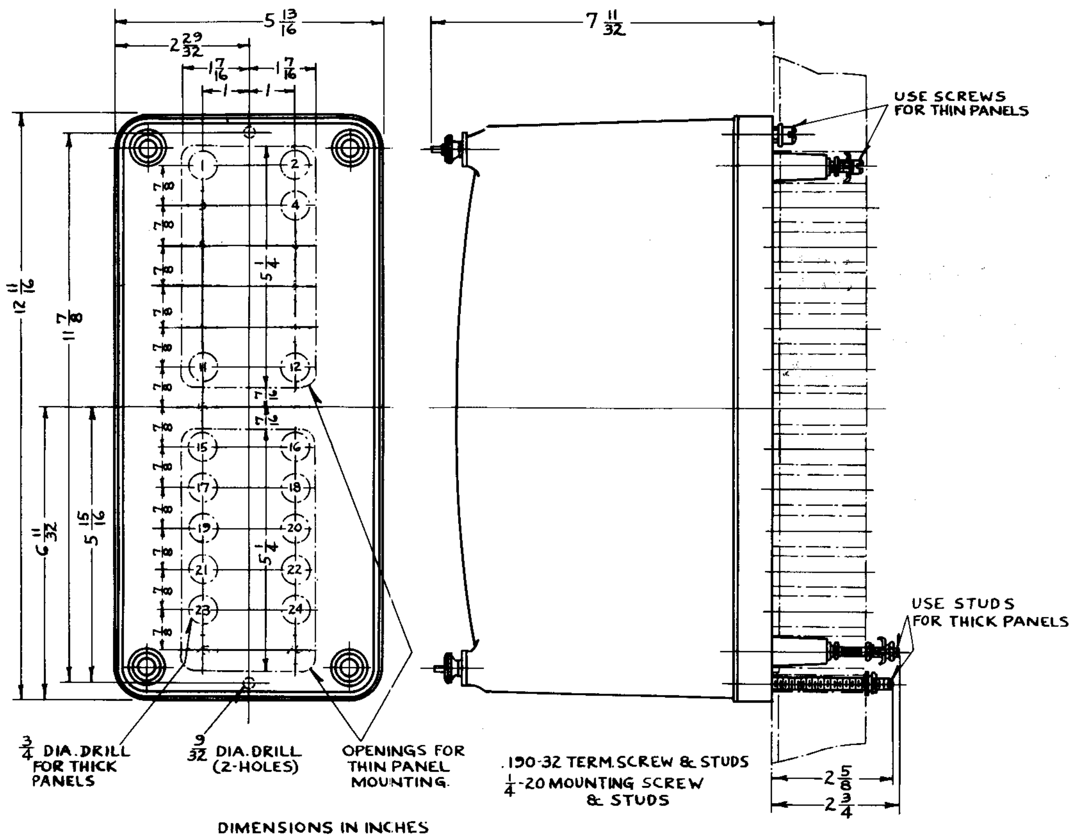


Figure 10
Outline and Drilling Plan for the Standard Projection Type Case.

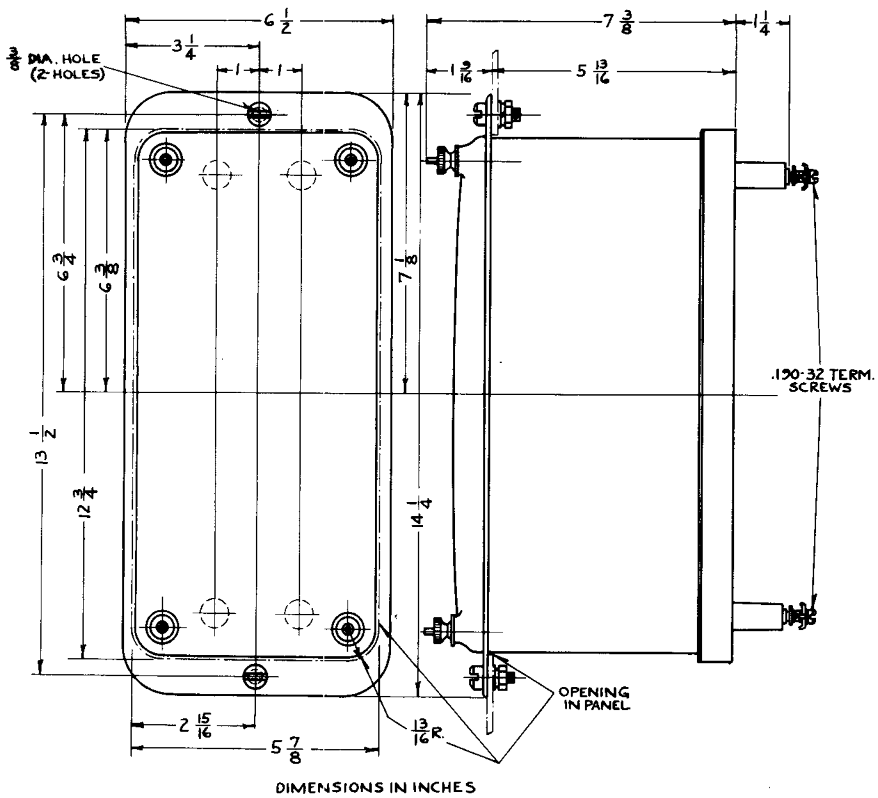


Figure 11
Outline and Drilling Plan for the Standard Flush Type Case.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

Type HZ-3 Impedance Relay

CAUTION Before putting protective relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type HZ-3 relay is a three element non-directional, high-speed relay with impedance elements of the balanced-beam type. The relay is used to supplement slow-speed relays on radial circuits. As applied to these circuits, the relay is used for phase fault protection over 80 to 90% of the line section, with the existing slow-speed relays protecting the remaining 20 to 10% and providing back-up protection.

The type HZ-3 relay is also used for phase and ground fault protection of station buses where the impedance of reactors in the feeder circuits connected to the bus is used as a means of discriminating between an internal and external fault.

CONSTRUCTION

The type HZ-3 relay contains three identical instantaneous impedance elements, a contactor switch, and three operation indicators. The elements are constructed as follows:

Impedance Element

Construction details of this element are shown in Figure 1. A balanced beam is pulled downward on the contact end by a current coil and on the other end by two voltage coils. The fluxes of these two potential coils are shifted out of phase with respect to each other to produce a steady pull. A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the element.

A rectangular silver contact is flexibly fastened on the forward end of the beam. As the beam trips, the contact bridges two silver stationary hemispherical contacts mounted on the free end of a short leaf spring. A small set screw determines the position of the leaf spring and provides means for adjusting the contact gap.

Contactor Switch

This is a small solenoid type d-c switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward the disc bridges three silver stationary contacts.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring restrained armature releases the white target which falls by gravity to show the completion of the trip circuit. The high speed action of the indicator is obtained by fastening a weight through a leaf spring to the armature. The added inertia causes the armature to continue its motion after the coil has been short-circuited. The indicator is reset from outside the case by a push rod.

Supersedes I.L. 41-417A

EFFECTIVE JUNE 1948

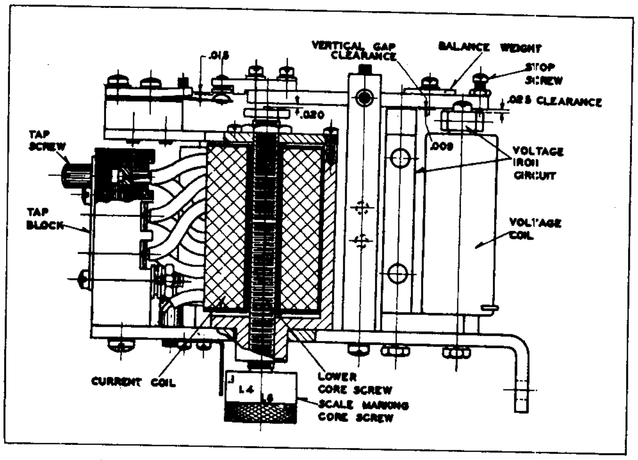


Fig. 1—Sectional View of the Impedance Elements.

OPERATION

The relay measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it. The relay is connected to receive a current and voltage proportional to those existing on the high-tension line. With a fault in the zone of the relay, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, the voltage at the relay must be equal to the drop in the line due to the current, I, or equal to IZ where Z is the impedance to neutral of the line from the relay to the point of fault. The ratio of the two values is $IZ/I = Z$. Thus, the ratio is constant for any value of current as the voltage on the relay is equal to the current times the line impedance. Therefore, if the impedance element is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at 80 to 90% of the line section, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs beyond this balance point, the beam will not trip as the voltage pull is the greater because of a larger amount of impedance and correspondingly larger potential restraint than for which the beam is balanced.

The trip circuit consists of the three impedance element contacts and the three operation indicator coils in parallel, and this combination in series with the contactor switch coil. When the relay contacts close, the coil is energized and its contacts short around the relay contacts, relieving them of the duty of carrying the breaker tripping current. These contacts remain closed until the trip circuit is opened by a breaker auxiliary switch. The operation indicators show a white target to indicate which of the three impedance element contacts close to complete the trip circuit.

CHARACTERISTICS

The relay is available in two impedance ranges: 0.6 to 6.0 ohms and 0.2 to 2.0 ohms. The difference in the two ranges is in the current coils of the impedance element and the corresponding tap markings. The tap and scale markings are as follows:

0.6 to 6.0 Ohm Relay

Taps - 6.2, 9.4, 13.5, 20.8, 29.8, 45

Core Screw Marking - .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4

0.2 to 2.0 Ohm Relay

Taps - 2, 3, 4, 6, 9, 13

Core Screw Marking - .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.6

SETTINGS

The type HZ-3 relay requires a setting for each of the three impedance elements. The following nomenclature will be used:

Z = the line-to-neutral ohmic impedance of the protected line from the relay to the 80 or 90% balance point.

R_C = The current transformer ratio

R_V = The potential transformer ratio

T = The impedance element current tap value

S = The impedance element current core screw value. The values appear as a series of dots on the drum of the lower core screw adjusting knob.

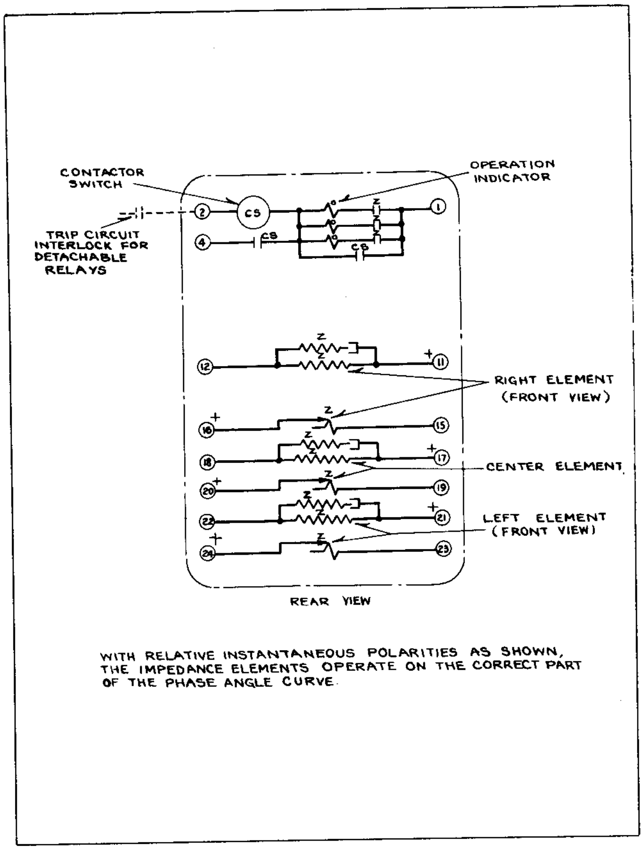


Fig. 2—Internal Schematic of the Type HZ-3 Relay in the Standard Case.

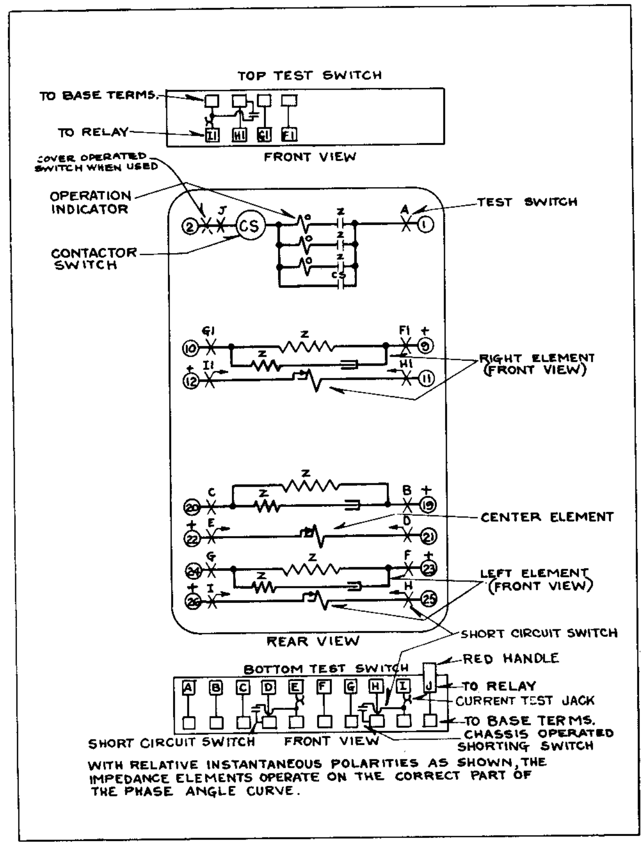


Fig. 3—Internal Schematic of the Type HZ-3 Relay in the Type FT Case.

Since the impedance of the voltage circuit of the relay is the same at all times, the balance point of the element is adjusted by changing the pull on the current coil. This is done by taps (T) on the current coil winding, and by the core screw (S) which varies the magnetic air gap for the current flux.

The most satisfactory method of arriving at the tap setting is by the use of the following formulas:

For Impedance Elements Receiving Delta Current Use:

$$TS = \frac{10Z\ R_c}{R_v} \qquad (1)$$

For Impedance Element Receiving Star Current Use:

$$TS = \frac{17.3Z\ R_c}{R_v} \qquad (2)$$

The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should be screwed in the desired tap before removing the existing tap screw to prevent open circuiting the current transformers.

The numbers on the core screw appear in ascending order as the core screw is screwed into the core. In some cases, a question of doubt may arise whether the scale setting is correct, or is out by one full turn of the core screw. In such a case, the point may be verified by turning the core screw all the way in. Then back out the core screw until the highest scale marking just comes under the end of the pointer. This will occur in less than 3/4 of a turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

The above formulas are based on the relay being used on a 60° line and are correct for lines of that angle. For lines other than 60° a slight error is introduced which may be as much as 8% and 6% on 40° and 80° lines, respectively. However, the formula relay setting can be corrected for lines other than 60° by using the curve of Figure 6. The scale reading should be decreased so that the current to trip the beam at the line angle is equal to the current to trip on a 60° line.

The formulae settings are sufficiently accurate for most installations. Where it is desired to set the balance point more accurately the tap and scale values may be checked by applying to the relay the voltage, current, and phase angle conditions which will be impressed on it for a fault at the desired balance point. A slight change in the scale value from that calculated may be required.

As an example of the formula setting, set the impedance elements to protect a 60°, 110 kv., 60 cycle line, 75 miles long. The line-to-neutral impedance is .75 ohm per mile. The current transformer ratio is 400/5, and the potential transformer ratio is 1000/1. Each element is to protect 90% of the line section or for a balance point .90 x 75 x .75 = 50.6 ohms away. Then

$$TS = \frac{10 \times 50.6 \times 80}{1000} = 40.5$$

Set tap = 29.8 and core screw = 1.36 on a 0.6 to 6.0 ohm relay. Since the relay is a three-phase relay, the settings for the second and third elements will be duplicate of the first as above.

RELAYS IN TYPE FT CASE

The type FT cases are dust-proof enclosures combining relay elements and knife-blade test switches in the same case. This combination provides a compact flexible assembly easy to maintain, inspect, test and adjust. There are three main units of the type FT case: the case, cover and chassis. The case is an all welded steel housing containing the hinge half of the knife-blade test switches and the terminals for external connections. The cover is a drawn steel frame with a clear window which fits over the front of the case with the switches closed. The chassis is a frame that houses the relay elements and supports the contact jaw half of the test switches. This slides in and out of the case. The electrical connections between the base and chassis are completed through the closed knife-blades.

Removing Chassis

To remove the chassis, first remove the cover by unscrewing the captive nuts at the corners. This exposes the relay elements and all the test switches for inspection and testing. The next step is to open the test switches. Always open the elongated red handle switches first before opening any of the black handle switches or the cam action latches. This opens the trip circuit to prevent accidental trip out. Then open all the remaining switches. The order of opening the remaining switches is not important. In opening the test switches they should be moved all the way back against the stops. With all the switches fully opened, grasp the two cam action latch arms and pull outward. This releases the chassis from the case. Using the latch arms as handles, pull the chassis out of the case. The chassis can be set on a test bench in a normal upright position for test as well as on its back or sides for easy inspection and maintenance.

After removing the chassis a duplicate chassis may be inserted in the case or the blade portion of the switches can be closed and the cover put in place without the chassis.

When the chassis is to be put back in the case, the above procedure is to be followed in the reversed order. The elongated red handle

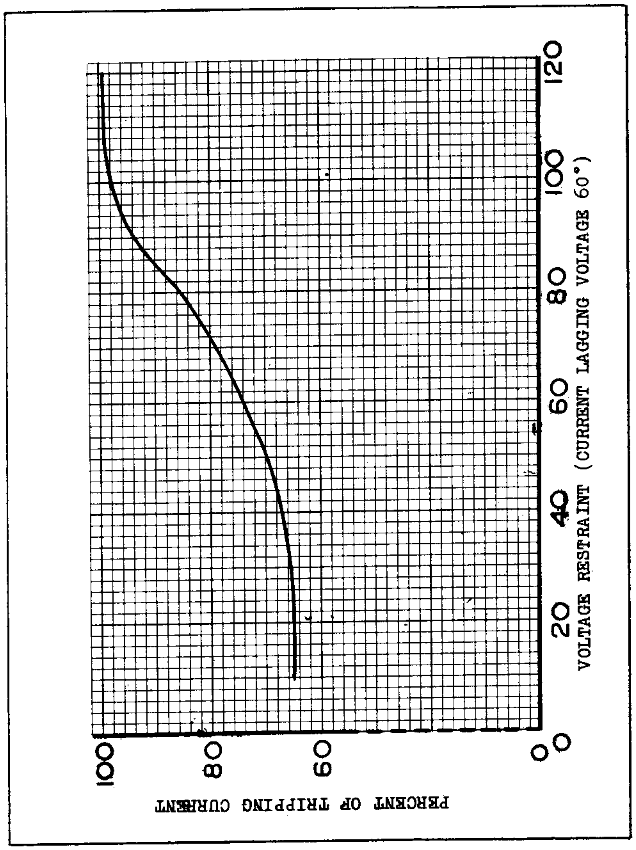


Fig. 5—Typical Reset Curves for the First Element.

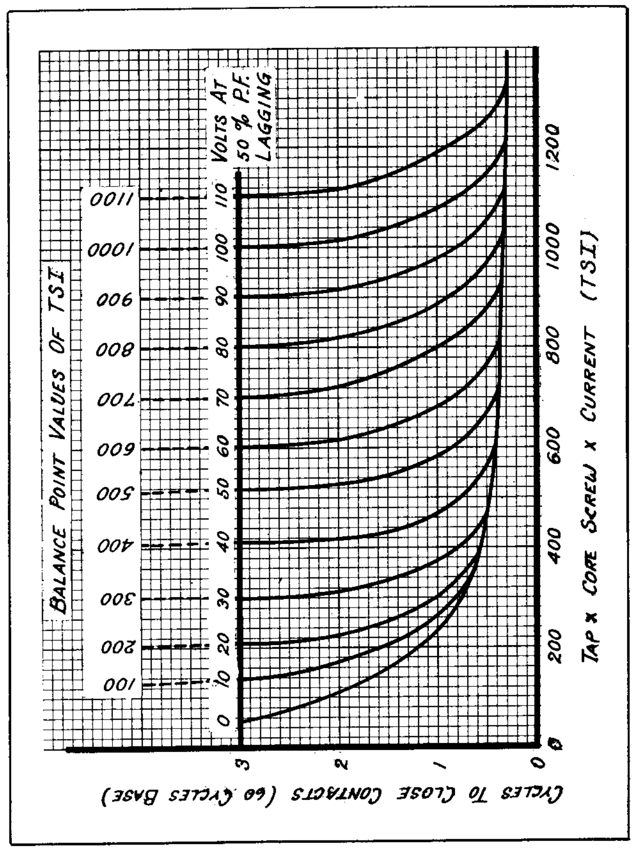


Fig. 7—Typical Time of Operation Curves for the First Element.

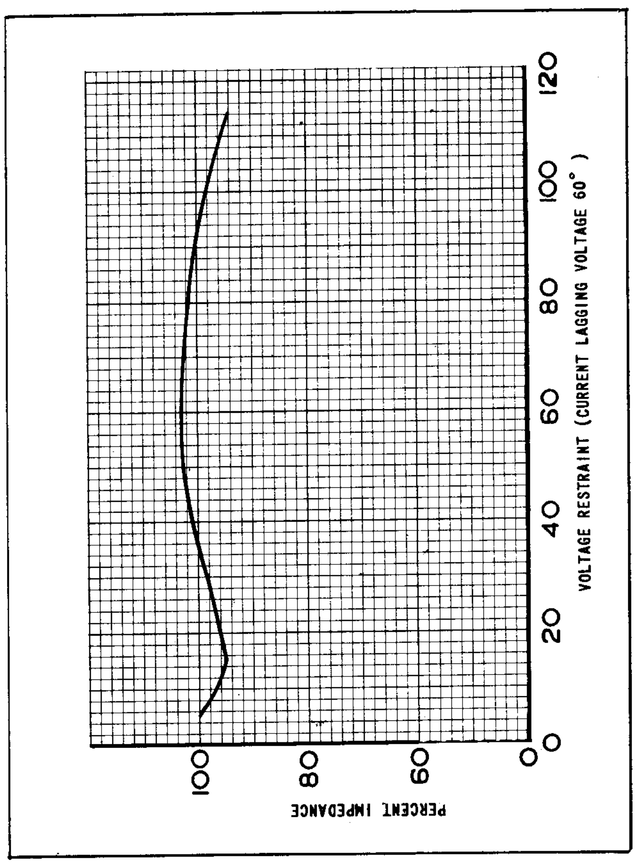


Fig. 4—Typical Impedance Curves for all Three Elements.

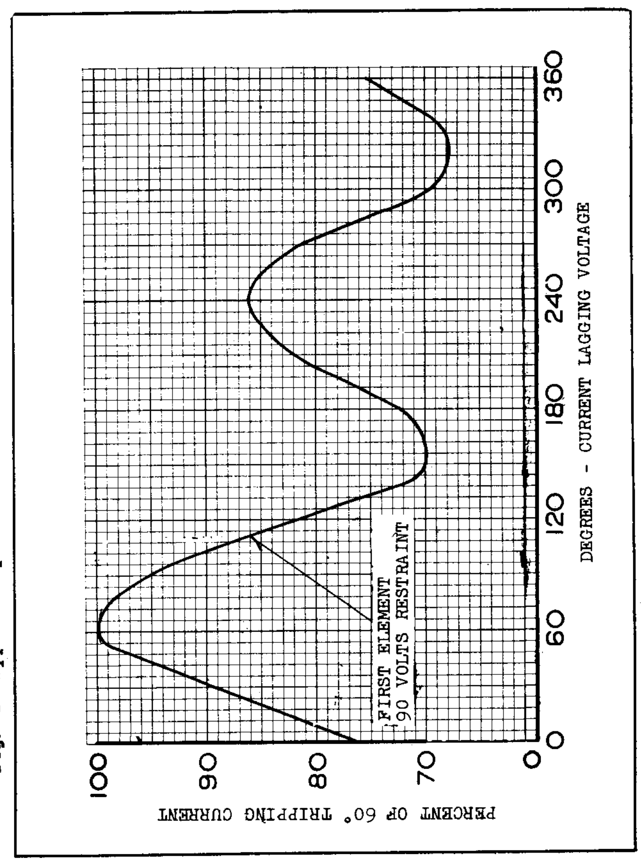


Fig. 6—Typical Phase Angle Curves for all Three Elements.

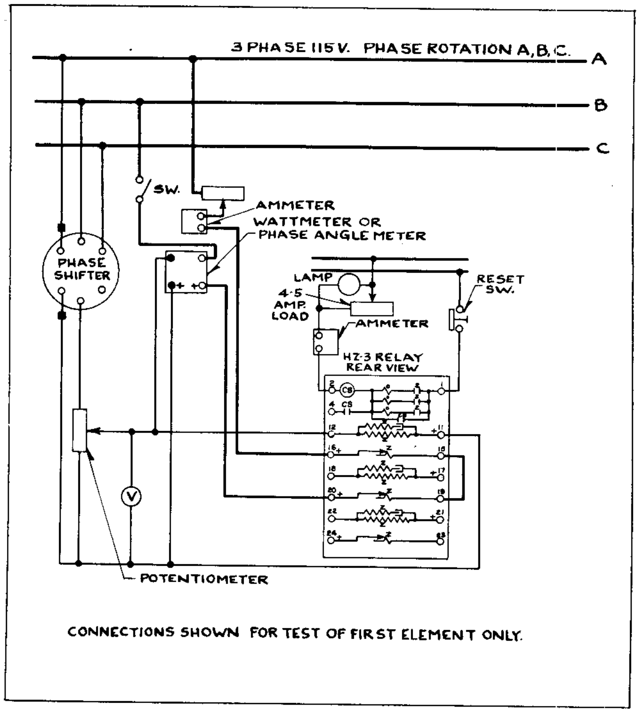


Fig. 8—Diagram of Test Connections for the Type HZ-3 Relay in the Standard Case.

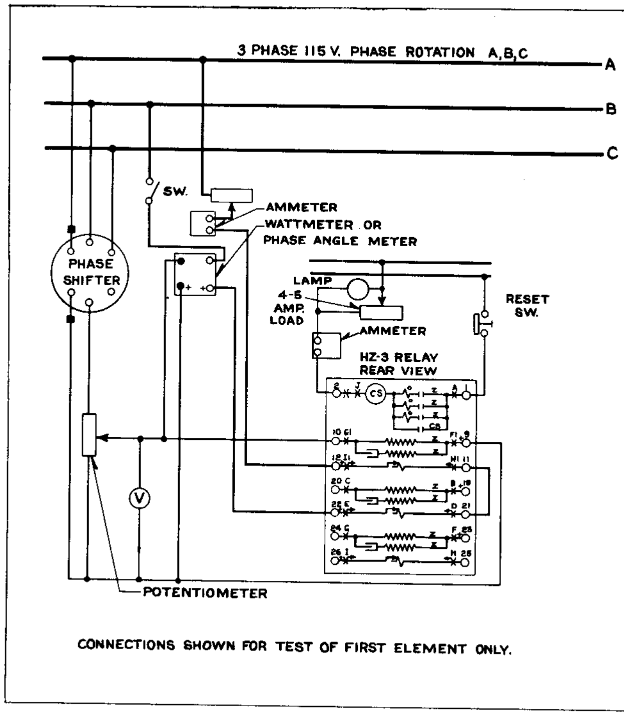


Fig. 9—Diagram of Test Connections for the Type HZ-3 Relay in the Type FT Case.

switch should not be closed until after the chassis has been latched in place and all of the black handle switches closed.

Electrical Circuits

Each terminal in the base connects thru a test switch to the relay elements in the chassis as shown on the internal schematic diagrams. The relay terminal is identified by numbers marked on both the inside and outside of the base. The test switch positions are identified by letters marked on the top and bottom surface of the moulded blocks. These letters can be seen when the chassis is removed from the case.

The potential and control circuits thru the relay are disconnected from the external circuit by opening the associated test switches. Opening the short circuiting test switch short-circuits that circuit and disconnects one side of the relay elements but leaves the other side of the element connected to the external circuit thru the current test jack jaws. This circuit can be isolated by inserting the current test plug (without external connections) by inserting the ten circuit test plug, or by inserting a piece of insulating material approximately 1/32" thick into the current test jack jaws. Both switches of the short circuiting test switch pair must be open when using the current test plug or insulating material in this manner to short-circuit the external circuit.

A cover operated switch can be supplied with its contacts wired in series with the trip circuit. This switch opens the trip circuit when the cover is removed. This switch can be added to the existing type FT cases at any time.

Testing

The relays can be tested in service, in the case but with the external circuits isolated or out of the case as follows:

Testing in Service

The ammeter test plug can be inserted in the current test jaws after opening the knife-blade switch to check the current thru the relay. This plug consists of two conducting strips separated by an insulating strip. The ammeter is connected to these strips by terminal screws and the leads are carried out thru holes in the back of the insulated handle.

Voltages between the potential circuits can be measured conveniently by clamping #2 clip leads on the projecting clip lead lug on the contact jaw.

Testing In Case

With all blades in the full open position, the ten circuit test plug can be inserted in the contact jaws. This connects the relay elements to a set of binding posts and completely isolates the relay circuits from the external connections by means of an insulating barrier on the plug. The external test circuits are connected to these binding posts. The plug is inserted in the bottom test jaws with the binding posts up and in the top test switch jaws with the binding posts down.

The external test circuits may be made to the relay elements by #2 test clip leads instead of the test plug. When connecting an external test circuit to the short-circuiting elements using clip leads, care should be taken to see that the current test jack jaws are open so that the relay is completely isolated from the external circuits. Suggested means for isolating this circuit are outlined above, under "Electrical Circuits."

Testing Out of Case

With the chassis removed from the case, relay elements may be tested by using the ten-circuit test plug or by #2 test clip leads as described above. The factory calibration is made with the chassis in the case and removing the chassis from the case will change the calibration values by a small percentage. It is recommended that the relay be checked in position as a final check of the calibration.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

CONNECTIONS

Impedance Element

The impedance to the balance point is measured from the point where the potential transformers are connected.

In some applications a power transformer bank forms part of the transmission line, and potential transformers are available only on the bus side of the bank. In this case the relays may be set thru the bank to protect the line only if the bank impedance is not too large as compared with the line impedance. If the bank impedance is too large in comparison with the line impedance, the 80 or 90% setting of the impedance element may cover only a very small percentage of the transmission line or in some cases not cover any of the line section. In order to use the potential transformers on the bus side of the bank under this condition, Type KX compensators are used and the impedance measured from the line side of the bank to the balance point. The type KX compensators (I.L. 41-540) operate from the current transformers and provide voltage compensation equivalent to the drop in the power bank.

The above discussion assumes that power is fed thru the bank to faults on the line. Where a power transformer connects to a high tension transmission line and does not supply power to a line fault, low-tension potential transformers may be used without compensation Then, the impedance to the balance point is measured from the point where the potential transformers connect to the protected line.

The conventional star connection of current transformers is not as satisfactory as the delta connection where accurate distance relay protection is desired. Witn this connection, the balance point of the impedance element shifts about 15% depending upon whether a phase-to-phase, a three phase or a double ground fault is involved. That is, if the balance point were adjusted at 80% for a three phase fault, then for a double ground fault the shift may be more or less than plus or minus 15% of the 80% setting, depending upon the relative magnitudes of the positive, negative and zero sequence impedance of the system from the source of power to the fault. This error can be entirely eliminated by making use of the vector difference between the line currents, (i.e. delta currents) for actuating the relay.

The most common method is to connect the main current transformers in star and use a set of auxiliary 5/5 ratio transformers to supply delta currents to impedance element, as shown in Figures 10 and 11. These auxiliary transformers need not be of very large volt-ampere capacity, as they supply only the impedance element coils which are of very low burden.

Trip Circuit

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 4 or 5 amperes in order to reduce the time of the operation of the switch to a minimum and provide more positive operation. If the relay is used to trip an auxiliary multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 3.8 ohms, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used.

The main contacts on the impedance elements will safely close 30 amperes at 250 volts d-c, and the switch contacts will safely carry this current long enough to trip the breaker.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be periodically cleaned with a fine file. S#1002110 file is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Impedance Elements

Refer to Figure 1. Adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the beam and the voltage iron circuit. With the beam in the reset position, i.e., with the stop screw against the stop, adjust the vertical gap for .009 inch between the adjustable iron and the beam. Care should be taken in this adjustment to keep the gap the same on both sides. Also, with the beam in the same position adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inch. The above values for the air gaps may be obtained by means of feeler gauges. It should be borne in mind, however, that the values given represent normal, or average values.

The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram. With any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint. In calibrating the first element, the same current should be passed thru the second element in the reverse direction thus simulating a phase-to-phase fault. In this way the small amount of electrical interference between elements is calibrated out. Similarly, the third element current coil should be energized in the reverse direction when calibrating the second element, and the first element current coil should be energized in the reverse direction when calibrating the third element. In the factory adjustment, this is done at T = 20.8 and S = 1.4 for the 0.6 to 6.0 ohm relay, and at T = 13, S = 1.6 for the 0.2 to 2.0 ohm relay.

The stationary contacts should be adjusted to give .015 inch clearance between them and the silver bridge on the beam when the beam is in the reset position. The bridge should be made to touch both contacts simultaneously, and deflect the contact springs at least .010 inch before the beam strikes the bronze stop on the core screw.

It is difficult to adjust accurately the contacts by eye. A good method consists in first adjusting one of the contacts to the correct gap and then applying just sufficient current to trip the beam against a restraint of about 5 volts. While the beam is in this position, that is, lightly pressing on the one contact, the other contact should be slowly adjusted upward by means of the set screw until it just touches the silver bridge without lifting it off the other contact. The trip circuit should be energized so that the lighting of a lamp or the tripping of an auxiliary relay will show when both contacts are made.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64" when the switch is picked up. This can be done by turning the relay up-side-down or by disconnecting the switch and turning it up-side-down. Then screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32" by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1 ampere d-c. Test for sticking after 30 amperes d-c have been passes through the coil.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed thru the coil. Adjustments may be made by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. Also, the amount of over-hand of the armature on the latch may be adjusted by means of the small screw bearing on the flat spring carrying the inertia weight. The best adjustment will usually be found when this screw just touches the flat spring with the armature in the reset position. If the two helical springs which reset the armature are replaced with new springs, they should be weakened slightly by stretching just beyond their elastic limit.

Calibration of Impedance Elements

The current required to operate the impedance elements against any given voltage is obtained from the equation:

$$TS = \frac{10\ E}{I} \qquad (3)$$

where T is the current tap and S is the setting of the calibrated core screw, E and I are the voltage and current respectively applied to the relay. Thus, if the setting is T = 20.8, S = 1.4 and the voltage is 35 volts, then the current required at 60° lagging is:

$$I = \frac{10\ E}{TS} = \frac{10 \times 35}{20.8 \times 1.4} = 12 \text{ amperes}$$

When checking the calibration, it is essential that the polarity as shown in the internal schematics be used, otherwise an error will be introduced.

The variation of tripping current for a given voltage as the phase angle between current and voltage is varied as shown in Figure 5. To make sure that the relay is operating at 60° lag and not 240°, the current leads can be reversed and the beam should operate on a smaller current if the connections were originally correct.

The general shape of the impedance curve for different ohm settings is shown in Figure 4. These curves are obtained by tripping the beam against different voltages for a constant T and S setting and then plotting the ratio E/I in percent of the 35 volt calibrating impedance against the voltage. The lower voltage points (5 to 15 volts) are considerably affected by the mechanical balance of the beam, while the higher points are but little influenced.

Accurate time tests on the instantaneous element can only be taken with the aid of an oscillograph or high-speed timer. The time of operation in cycles (60 cycle per second basis) of the impedance element for various balance points is given in Figure 7. By using these curves the operating speed can be determined for any value of the current or voltage applied to the element.

Caution

Make certain that the stops on the rear and front of the beam are absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

Also, when checking the impedance element at low voltage, observe the tripping of the beam instead of an indication in the trip circuit. This will prevent an error in the contact adjustment which might otherwise affect the beam calibration.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

The 60 cycle burden of the various circuits of this relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	V.A.	P.F. Angle
Impedance Element (each)	2.0	20° lag

CURRENT CIRCUITS

Circuit	Tap	Amps	V.A.	P.F. Angle
Impedance Element	45	8.66	6	42°
	13.5	8.66	1.3	22°
Auxiliary Star-Delta C.T. S#869125 5Y/8.66△5 See I.L. 41-535			3.5	10°

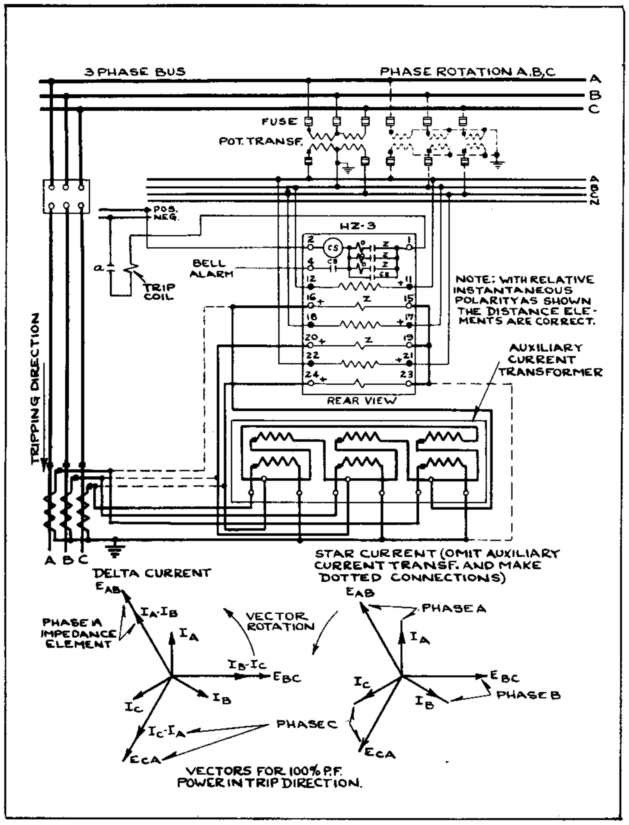


Fig. 10—External Connections of the Type HZ-3 Relay in the Standard Case for Phase Fault Protection Using Either Star or Delta Current in all Elements.

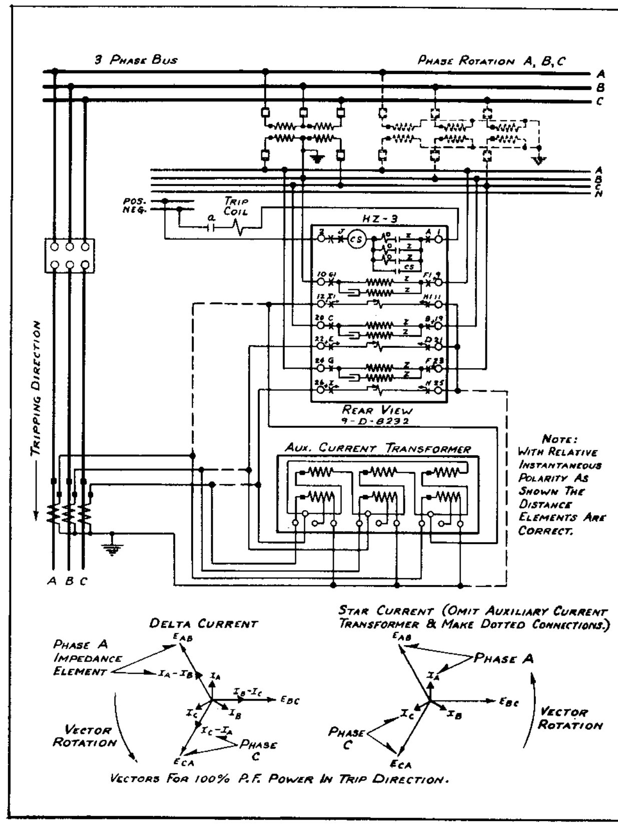


Fig. 11—External Connections of the Type HZ-3 Relay in the Type FT Case for Phase Fault Protection Using Either Star or Delta Current in all Elements.

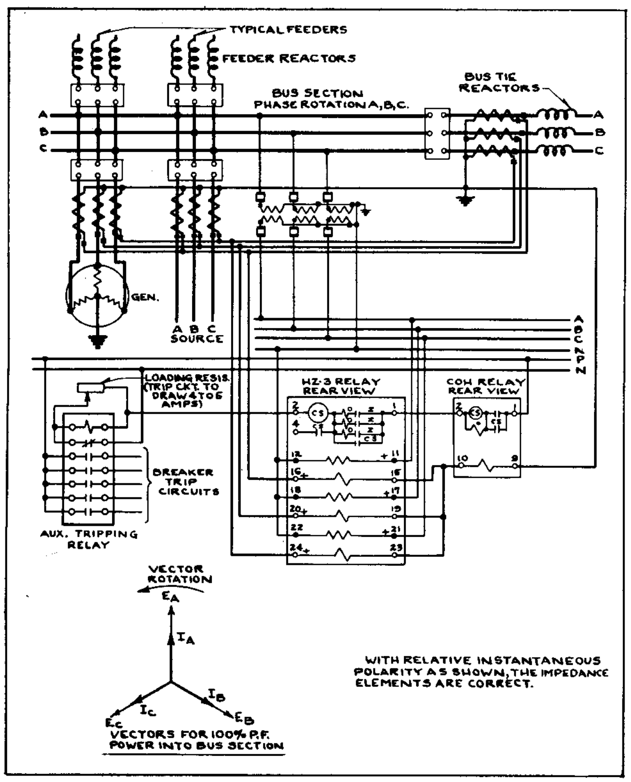


Fig. 12—External Connections of the Type HZ-3 Relay in the Standard Case for Phase-to-Ground Fault Protection on a Bus Section with Feeder Reactors.

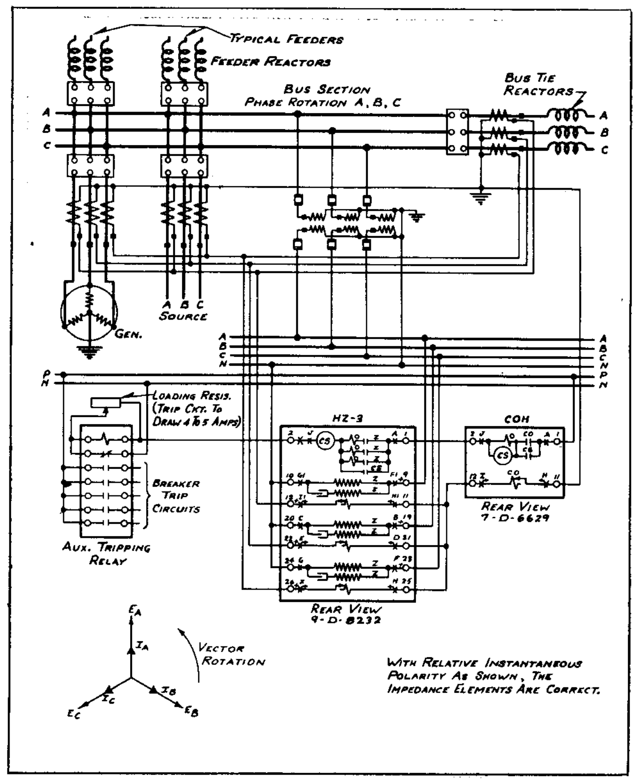


Fig. 13—External Connections of the Type HZ-3 Relay in the Type FT Case for Phase-to-Ground Fault Protection on a Bus Section with Feeder Reactors.

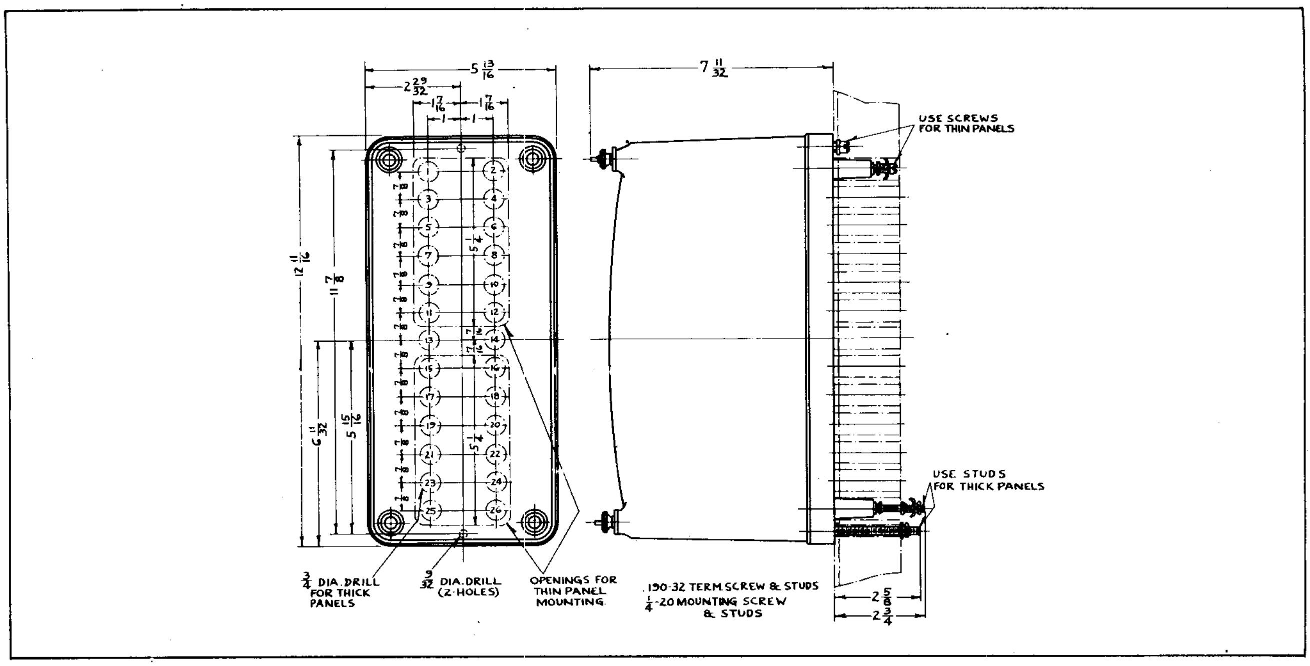


Fig. 14—Outline and Drilling Plan of the Standard Projection Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

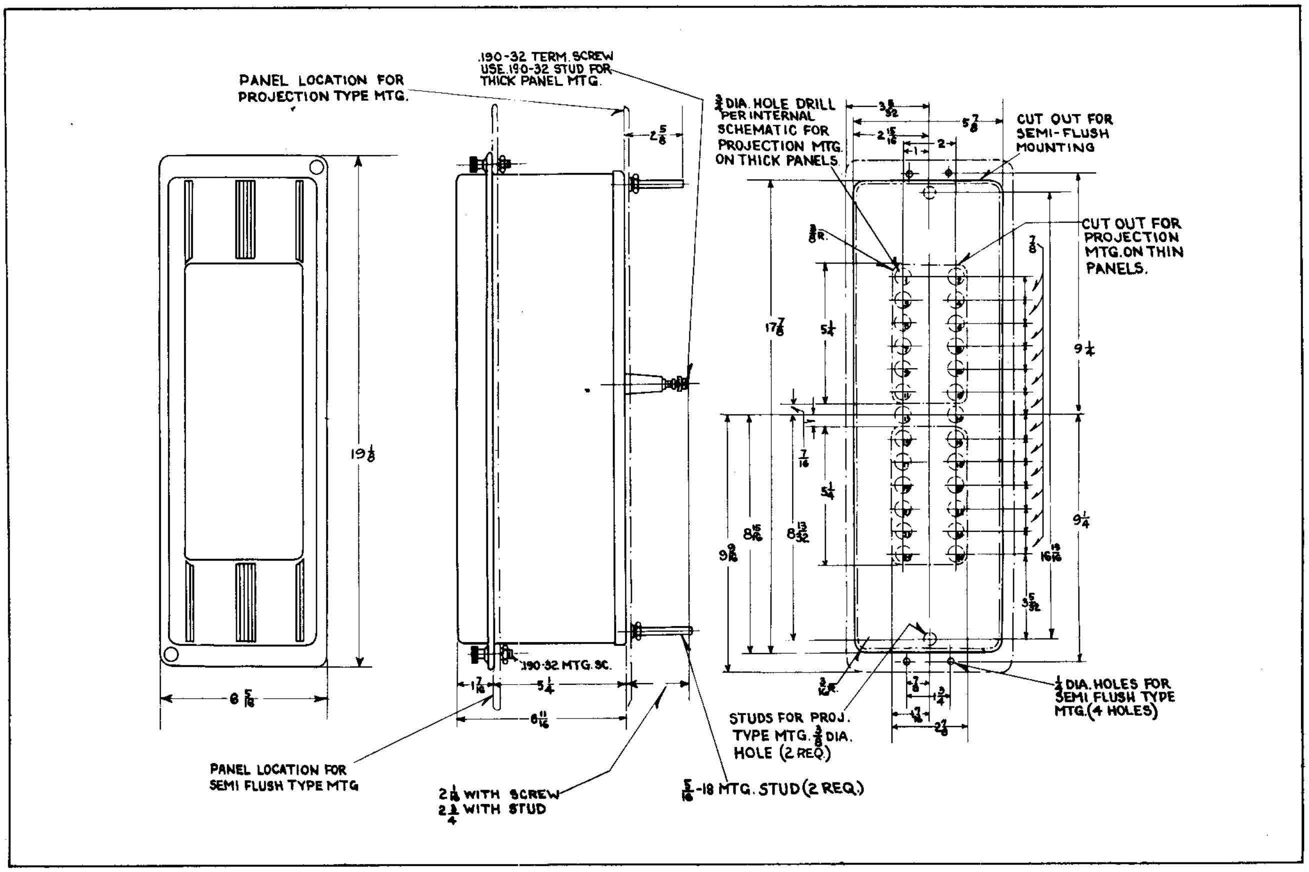


Fig. 15—Outline and Drilling Plan of the M20 Semi-Flush or Projection Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.