INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE HZ-1 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-1 relay is a single unit high speed impedance relay with an impedance unit of the balanced beam type and a high speed directional unit. The relay is used for directional phase fault protection over 80 to 90% of the transmission line section and supplements the existing slow speed relays which protect the remaining 20 to 10% and provide back up protection.

CONSTRUCTION

The type HZ-1 Relay contains an instantaneous impedance unit, a directional unit, a contactor switch, and an operation indicator. The units are constructed as follows:

Impedance Unit

Construction details of this unit are shown in Fig. 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 unit permits changing the number of turns on the current coil, and a core screw on the bottom of the unit changes an air gap in the magnetic path. These two adjustments make it possible to set the unit.

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.

Directional Unit Single Loop

The voltage coil of the directional unit serves as the primary winding of a small transformer. The secondary winding consists of a one turn movable coil, or loop, pivoted along its center line. This loop carries a current which is proportional to and substantially in phase with the voltage applied to the primary winding. The pivoted loop has a portion of its length lying in a magnetic field established by the current coils of the directional unit. The interaction of the current in the loop with the flux established by the current coils produces torque which rotates the loop in one of two directions, depending upon the phase angle relationship between the applied current and the applied voltage.

A ceramic arm extends from the moving loop and supports a rectangular silver contact which bridges two stationary contacts located on the right of the loop. The stationary contacts are silver hemispheres mounted on the lower end of vertically-hanging spring leaves. The contact separation is adjustable by a small screw near the upper end of the rigid stationary contact supporting arm. One of these supporting arms hangs parallel to each of the two stationary contacts. The set screw on the lower end of this arm provides the contact follow adjustment. An additional screw on the movement frame beneath the current coil iron limits the movement of the one-turn loop to the left.

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.

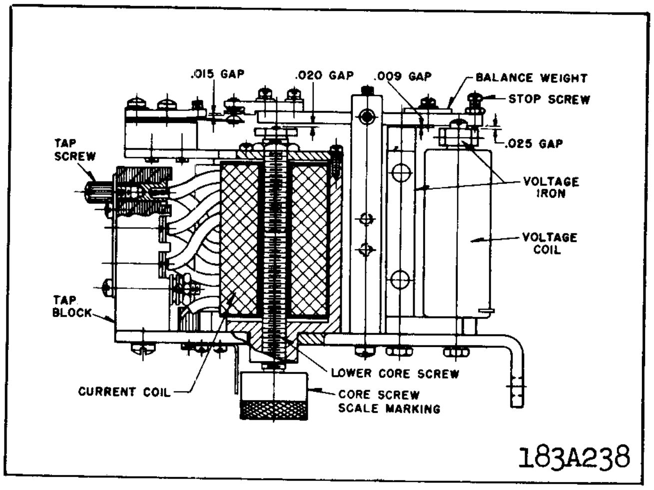

Fig. 1. Sectional View of the Impedance Unit.

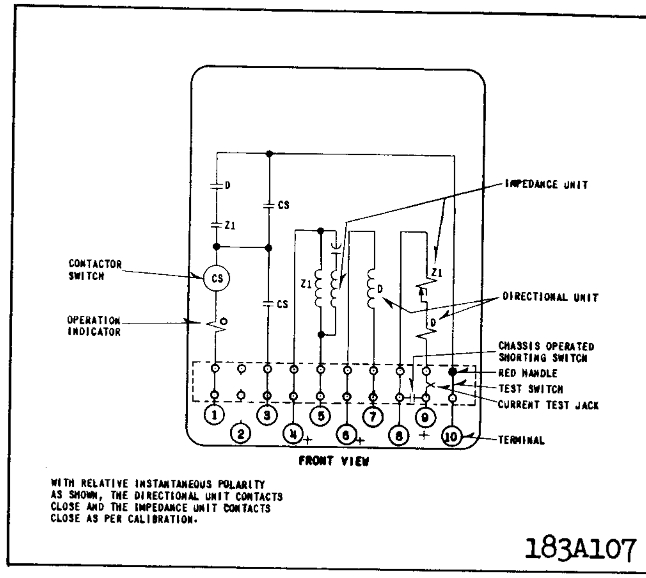

Fig. 2. Internal Schematic of the Type HZ-1 Relay in the Type FT21 Case.

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.

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, the impedance unit 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 directional unit contacts are in series with the impedance contacts so that the fault current must be flowing away from the bus on the line being protected before the relay can operate. The coil of the contactor switch is connected in the trip circuit. 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 third contact of the contactor switch is connected to a separate relay terminal to operate an alarm circuit. The operation indicator shows a white target when the trip circuit is completed.

The operation of the impedance unit is not dependent on the operation of the directional unit, that is, it is not directionally controlled. Directional control is unnecessary because the impedance unit is so fast in operation that it will open contacts before the directional contacts can close (as on a reversal of power flow after a fault has been cleared elsewhere). Likewise, the directional contacts will always open before the impedance contacts can close.

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 unit 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, 1.2, 1.4

0.2 to 2.0 Ohm Relay

Taps – 2, 3, 4, 6, 9, 13
Core Screw Marking – .8, .9, 1.0, 1.2, 1.4, 1.6

SETTINGS

The type HZ-1 relay requires a setting for the impedance unit. The following nomenclature will be used:

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

R_C = The current transformer ratio

R_V = The potential transformer ratio

T = The impedance unit current tap value

S = The impedance unit current core screw value. The values appear 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 unit 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 Unit Receiving Delta Current Use.

$$TS = \frac{10Z\, R_C}{R_V} \qquad (1)$$

For Impedance Unit Receiving Star Current Use.

$$TS = \frac{17.3\, Z\, R_C}{R_V} \qquad (2)$$

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 approximately one 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 Fig. 3. 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 formula 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 unit 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. The impedance unit 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.

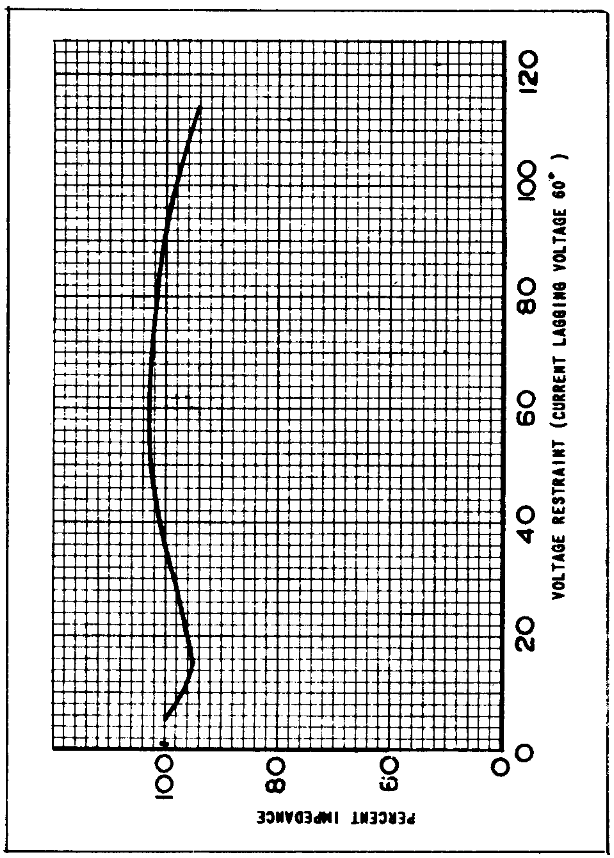

Fig. 3. Typical Impedance Curve for the Impedance Unit.

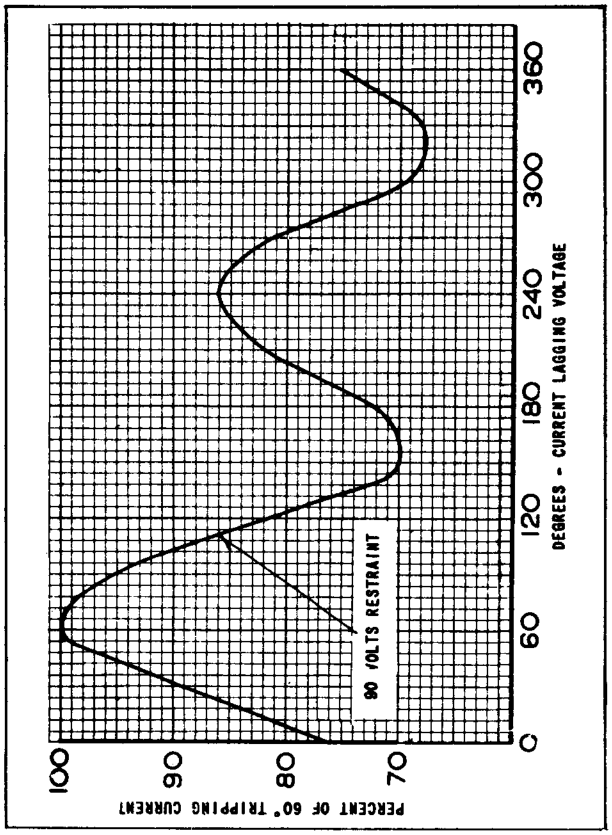

Fig. 4. Typical Phase Angle Curve of the Impedance Unit.

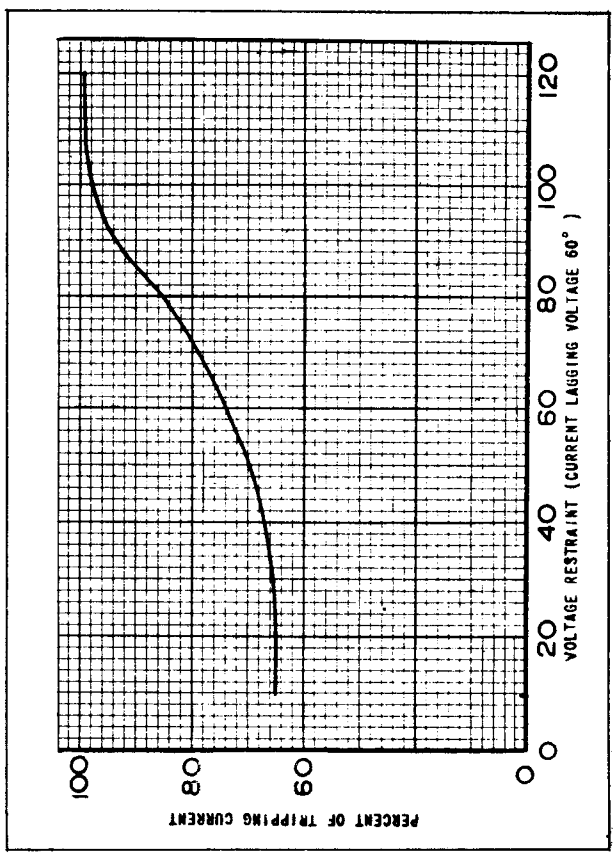

Fig. 5. Typical Reset Curve for the Impedance Unit.

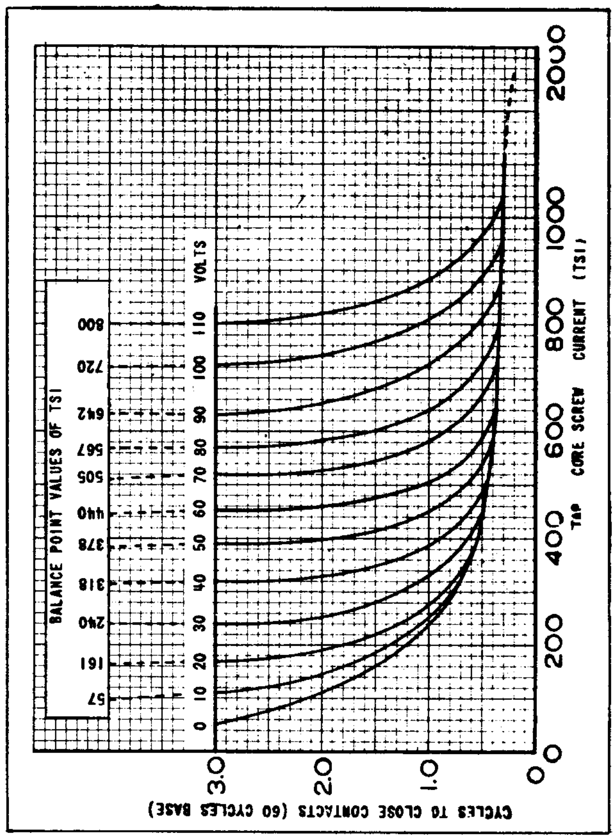

Fig. 6. Typical Time of Operation Curves for the Impedance Unit.

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 four mounting holes on the flange for semi-flush mounting or by means of of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

CONNECTIONS

Impedance Unit

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 unit 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 power bank connects to the protected line.

The conventional star connection of current transformer is not satisfactory where accurate distance relay protection is desired. With this connection the balance point of the impedance unit 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 ratio of the zero sequence impedance to the negative 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 current to the impedance unit, as shown in Fig. 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.

Directional Unit

The directional unit coils should be connected to receive current that leads the voltage by 60^{o}, when the line power factor is 100%. The advantage of connecting the directional unit in this manner is that for anything except a three-phase fault the voltage applied to the relay required to trip will be equal to, or in excess of, the normal line-to-neutral voltage.

The polarity of the current and the voltage coils should be as indicated on the internal and external schematic diagrams.

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 on 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 1.0 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 unit and

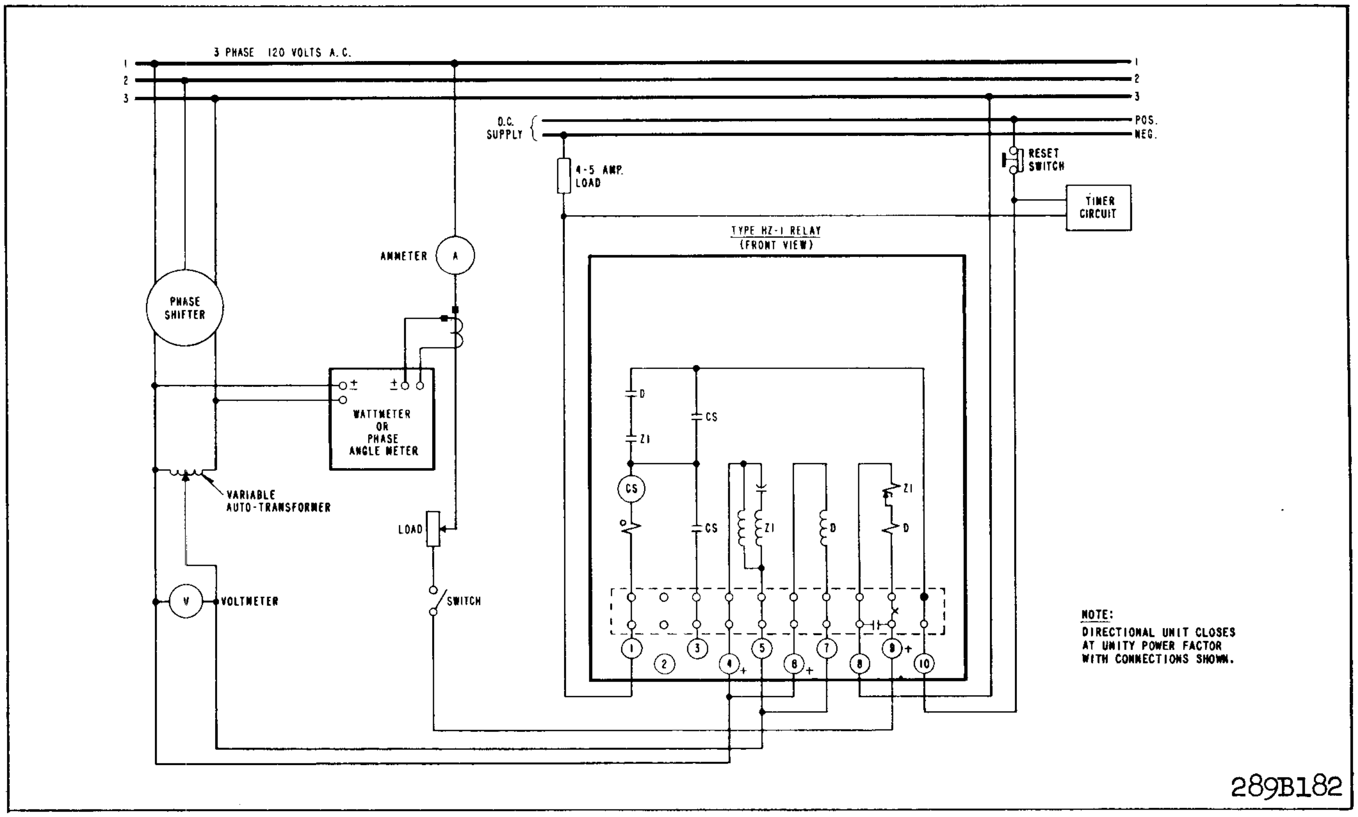

Fig. 7. Diagram of Test Connections for the Type HZ-1 Relay.

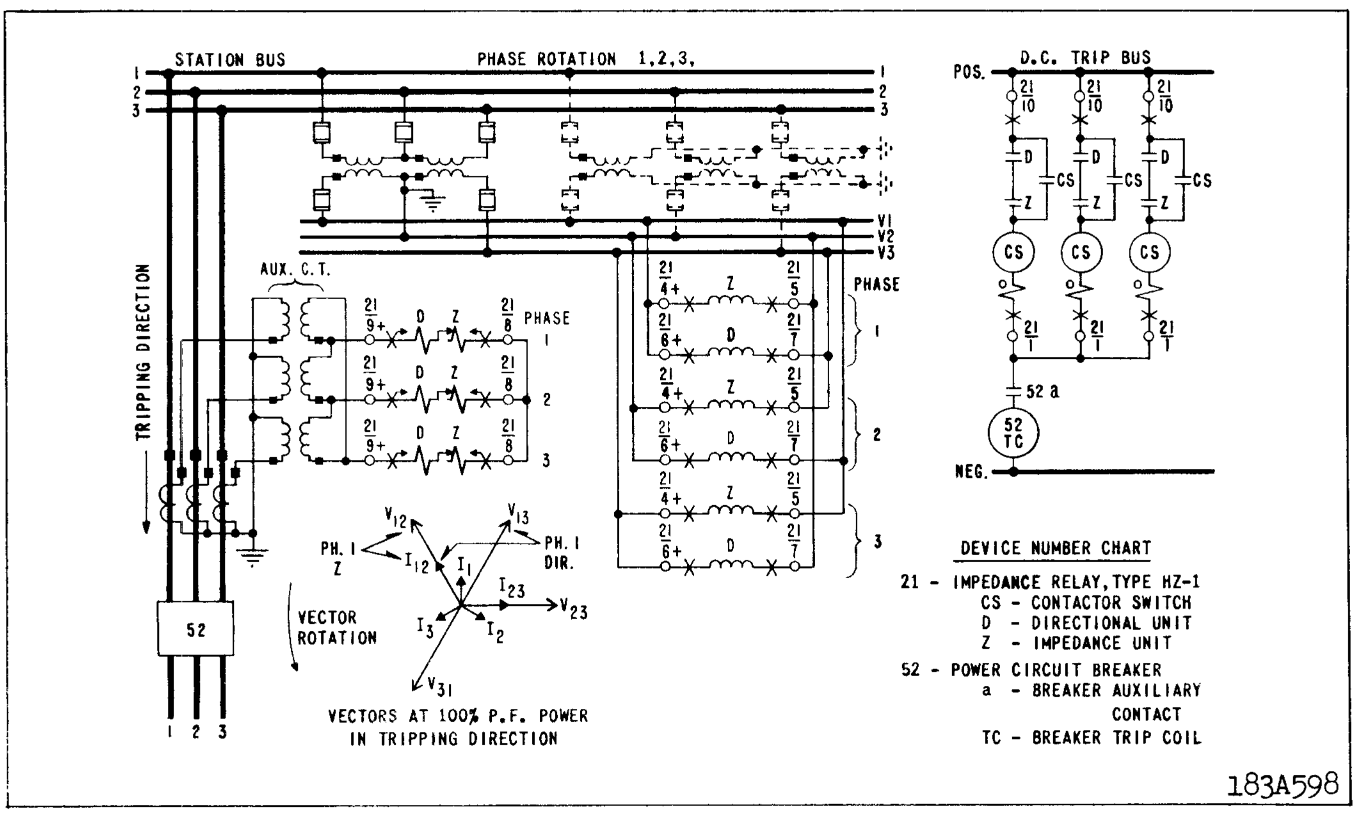

Fig. 8. External Schematic of Type HZ-1 Relay for Phase Protection.

directional unit will safely close 30 amperes at 250 volts d-c., and the switch contacts will safely carry this current long enough to trip a 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 or the relay taken apart for repairs, the following instructions should be followed in reassembling and setting it.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 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 Unit

Refer to Fig. 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 inches between the adjustable iron and the beam. 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 actual gaps on any particular relay may vary a few thousandths from these values.

The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram, Fig. 7.

CAUTION: The relay voltage should be of good wave form. The combination of a phase shifter and autotransformer may give an output voltage of poor wave form if the magnetizing current of the autotransformer is high in proportion to the impedance of the phase shifter used. In case of doubt, check the output voltage wave form with an oscilloscope.

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 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.

A good method of adjusting the contacts 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.

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 inch before the beam strikes the bronze stop on the cores screw.

Directional Unit

Check the free movement of the directional unit loop with the relay in a vertical position to see that it is free from friction and properly centered. The loop should assume a vertical position with the contacts open when the unit is completely de-energized.

With the loop in the vertical position adjust the stationary contacts for .020 inch separation from the vertical moving contact. Adjust the contact back stop screw to just touch the stationary contacts, then back off 1/2 of a turn to give correct contact follow. Adjust the stop screw which limits the movement of the loop to the left (this screw is located at the rear of the current coil) so that the loop just strikes this stop when de-energized.

Too much follow on the directional contacts should be avoided in order to allow the directional unit to reset fast enough by gravity to properly coordinate with the high speed impedance unit.

Energize the loop with normal potential long enough to bring it up to temperature (about 10 or 15 minutes) and adjust the bearing screws so there is about .010 inch end play. See that the loop does not bind or strike against the iron or coil when pressed against either end jewel.

The minimum pick-up of the unit is 10 amperes at 2.0 volts (unity power factor). Apply these values to the unit and see that the contacts make good contact in the correct direction. Reverse the direction of current to see that the contacts open.

When the directional unit is energized on voltage alone, there may be a small torque which may hold contacts either open or closed. This torque is small and shows up only at high voltages with the entire absence of current. At voltages high enough to make this torque discernible, it will be found that only a fraction of an ampere in the current coils will produce wattmeter torque to insure positive action. This is mentioned because the slight torque shown on voltage alone has no significance in actual service and has no practical effect on the directional unit operation.

Check the coordination of the directional and impedance contacts as follows. Set the impedance unit on the maximum tap and scale setting. Connect the relay with the correct polarity, as shown in test diagram, Fig. 7. Apply 115 volts a-c. to the impedance and directional unit potential coils and pass 5 amperes at unity power factor thru the current circuit. Check trip circuit to see that it is not completed when the voltage on the impedance and directional units is suddenly applied or interrupted. Do not interrupt the current circuit. Make several such tests. The trip circuit should draw about 5 amperes d-c. for this test so that the contactor switch will pick up and seal in if the units fail to coordinate. This coordination test has been described for the most severe conditions. Consequently, an occasional failure to coordinate may be tolerated, since, in service, the directional unit will be resetting under the positive action of reverse power flow rather than under the influence of gravity alone, as described in this test. If proper coordination is not obtained, it may be necessary to reduce the follow on the directional or impedance unit contacts, as the case may be.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving cord 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. are passed thru the coil.

Calibration of Impedance Units

The current required to operate the impedance unit 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 Fig. 7, otherwise an error will be introduced.

Fig. 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.

Fig. 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 ratic 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 unit and directional unit can only be taken with the aid of an oscillograph or high speed timer.

Fig. 6 shows the time of operation in cycles (60 cycles per second basis) of the impedance unit for various balance points. By using these curves the operating speed of the HZ unit can be determined for any value of current and voltage applied to the unit.

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 unit 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 120 VOLTS

Circuit	V.A.	P.F. Angle
Impedance Unit	2.2	20° lag
Directional Unit	4.0	20° lag

CURRENT CIRCUITS

Circuit	Tap	Amps.	V.A.	P.F. Angle
Impedance Unit	45	8.66	6	42°
	13.5	8.66	1.3	22°
Directional Unit		5.	1.1	42°
Auxiliary Star-Delta C.T. S#879127	5Y/8.66Δ	5.	3.5	10°

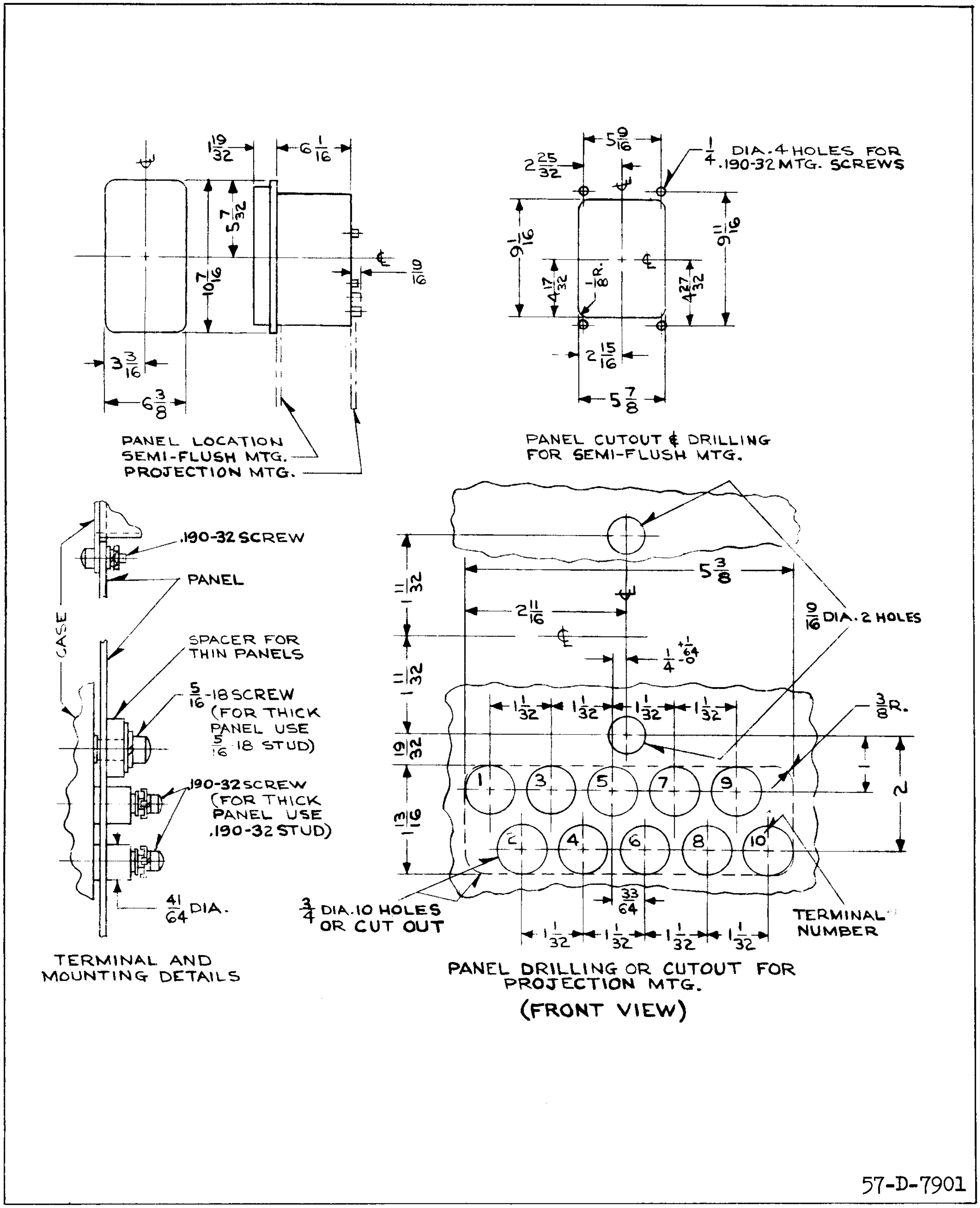

Fig. 9. Outline and Drilling Plan of the Type HZ-1 Relay in the Type FT21 Case.

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