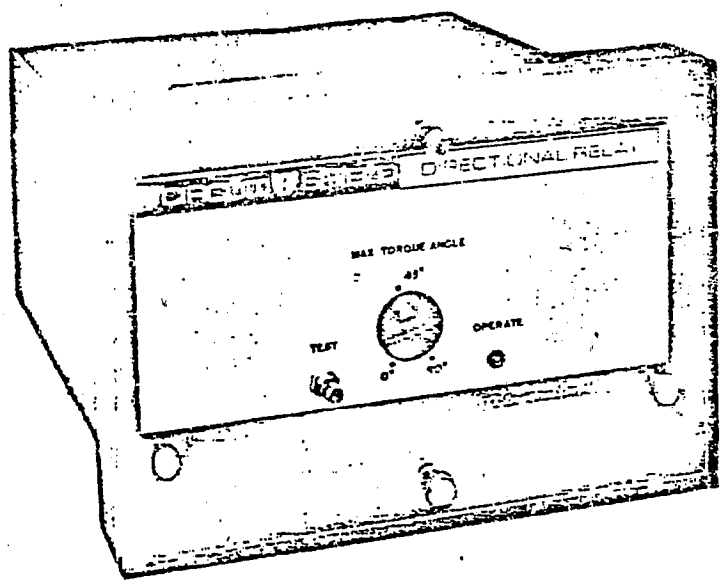
SOLID-STATE DIRECTIONAL RELAYS
INSTRUCTIONS

CIRCUIT-SHIELD™
DRAWOUT SEMI-FLUSH MOUNTED

POLYPHASE DIRECTIONAL RELAYS

Type ITE-32 , Positive-Sequence Directional Relay
Type ITE-32Q, Negative-Sequence Directional Relay



GOULD-BROWN BOVERI

TABLE OF CONTENTS

INTRODUCTION

These instructions contain the information required to properly install, operate and test the ITE-32 and ITE-32Q solid-state directional relays.

The relay is housed in a semi-flush drawout relay case suitable for conventional panel mounting.

All connections to the relay are made at terminals located on the rear of the case and clearly numbered.

All controls are mounted on the front panel behind a clear cover.

PRECAUTIONS

The following precautions should be taken when applying solid-state relays:

1. Incorrect wiring may result in damage to solid-state relays. Be sure wiring agrees with the connection diagram for the particular relay before the relay is energized. Be sure control power is applied in the correct polarity before applying control power.

2. Apply only the rated control voltage marked on the relay front panel. For relays with dual rated control voltage, withdraw the relay from the case and check that the movable wire on the circuit board is in the correct position for the system control voltage.

3. Do not attempt to manually operate target vanes on these relays. Although the targets return their indication under shock, they can be damaged by manual operation with a pencil or pointed object.

4. Do not apply high voltage tests to solid-state relays. If a control wiring insulation test is required, bond all terminals together and disconnect ground wire before applying test voltage.

5. Only the lower circuit board of these relays is removable. This board should insert smoothly. Do not use force.

6. Follow test instructions to verify that the relay is in proper working order.

PLACING THE RELAY INTO SERVICE

1. RECEIVING, HANDLING, STORAGE

Upon receipt of the CIRCUIT-SHIELD relay (when not included as part of a switchboard) examine for shipping damage. If damage or loss is evident, file a claim at once and promptly notify the nearest Gould-Brown Boveri Sales Office. Keep clean and dry and use normal care in handling to avoid mechanical damage.

2. INSTALLATION

Mounting

The outline dimensions and panel drilling and cutout information is given in Figure 1.

Connections

All I-T-E Protective Relays have metal front panels which are connected through printed circuit board runs and connector wiring to a terminal at the rear of the relay case. The terminal is marked "G" and is located as shown in Figure 1. In all applications this terminal should be wired to ground.

Before energizing the relay, the relay element should be withdrawn from its case, and a visual check be made to insure that the movable control voltage selection wire has been placed on the correct terminal for the system control voltage. Models rated for 250Vdc control power include a dropping resistor mounted on the outside of the case.

Output Contacts

Two styles of output contacts are used in these relays:

1) Models with sealed reed type output contacts are preferred when the directional relay is used to torque-control a type ITE-51 overcurrent relay. These models also have a self-resetting light emitting diode operation indicator, which is lighted when the current is in the tripping direction.

2) Models with heavier duty telephone relay type output contacts are preferred when the directional relay will be used to operate other devices, such as a lock-out relay, or auxiliary relay, or trip a circuit breaker, as in reverse power schemes. These models have a hand-reset target indicator.

Directional Overcurrent Relay Applications

Connections for the ITE-32 controlling an ITE-51 three phase overcurrent relay are shown in Figure 2. Connections for the ITE-32Q controlling an ITE-51 residual overcurrent relay are shown in Figure 3.

Overcurrent Relay Shorting Links (Torque Control)

When using the ITE-50 and ITE-51 relays with these directional relays, one or more of the shorting links on the rear terminals of the overcurrent relay must be removed according to the application. See Figures 2 and 3 for connections and instructions for removing these links.

3. SETTINGS

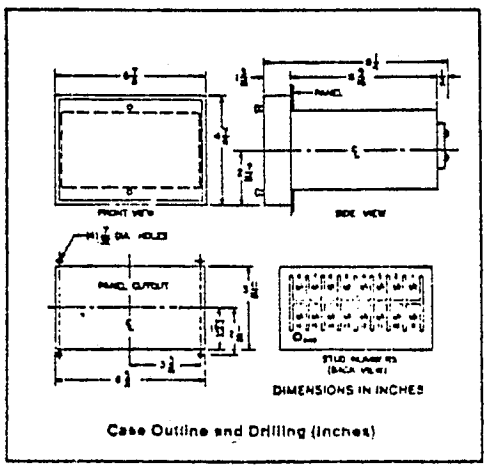
Maximum Torque Angle

This front-panel adjustment must be set properly according to the applications. Refer to the APPLICATIONS section for recommended settings.

For the ITE-32, the Maximum Torque Angle equals the front panel dial setting. For the ITE-32Q, the Maximum Torque Angle equals 180 degrees minus the dial setting.

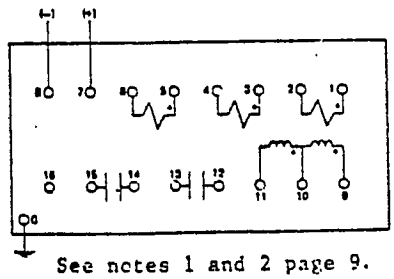
Sector Width Adjustment

Certain models are provided with an adjustment which changes the tripping angle of the relay from 180° to a smaller angle. Refer to the APPLICATIONS section for recommended settings, and to the testing section for procedure.



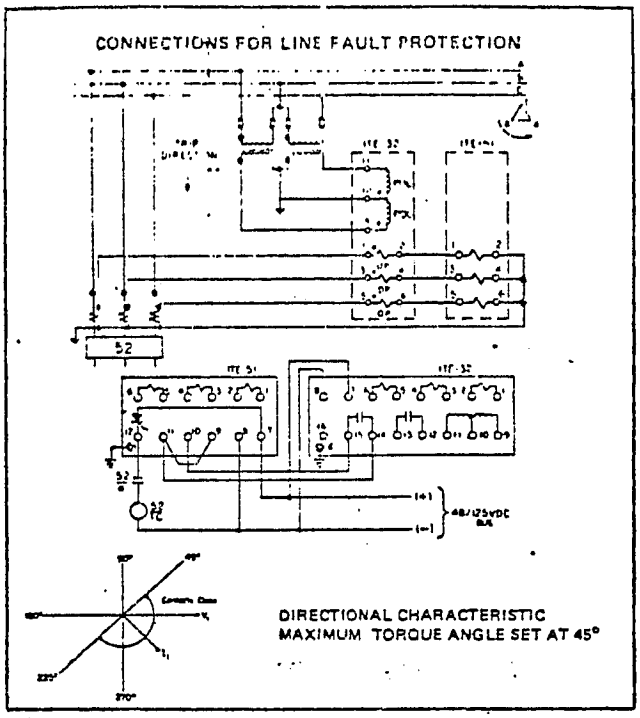
Case Outline and Drilling (Inches)

16D225A
DIRECTIONAL RELAYS
TYPES ITE-32, ITE-32C



See notes 1 and 2 page 9.

Figure 1:
Outline and Internal Connections



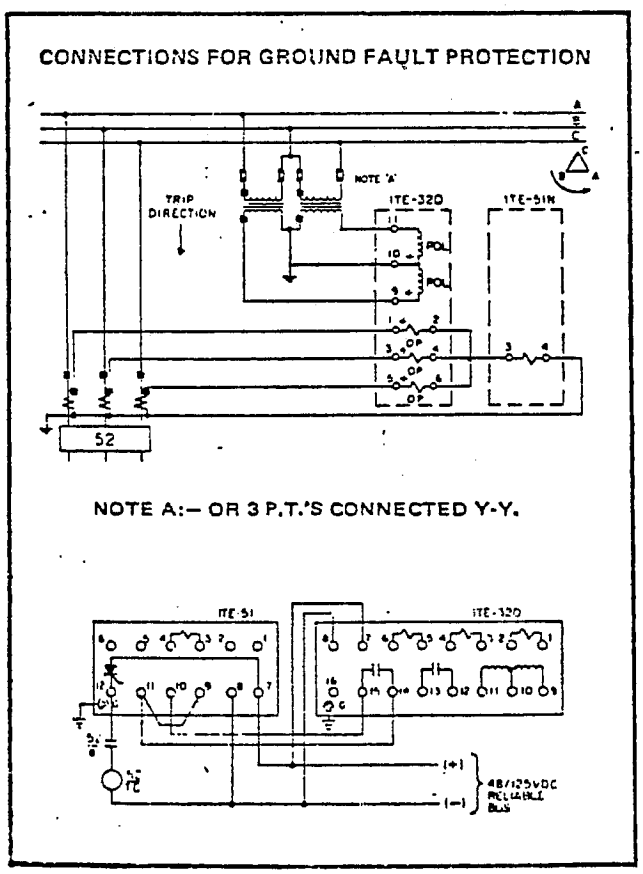
TORQUE CONTROL CONNECTIONS

To control TIME and INST function:
a. Remove links 9-10 and 10-11 supplied on ITE-51.
b. Connect as shown in diagram on left.

To control only the TIME function:
a. Remove link 10-11 on ITE-51:
b. Connect as shown in diagram on left, EXCEPT omit jumper 9-11 on ITE-51.

To control only the INST function:
a. Remove link 9-10 on ITE-51.
b. Connect as shown in diagram on left, EXCEPT omit jumper 9-11 on ITE-51 and move wire starting at ITE-32-(14) from terminal 11 to terminal 9 on the ITE-51.

FIGURE 2 - CONNECTIONS FOR DIRECTIONAL LINE FAULT PROTECTION (Types ITE-32 and ITE-51)



TORQUE CONTROL CONNECTIONS

To control TIME and INST functions:
a. Remove links 9-10 and 10-11 supplied on ITE-51.
b. Connect as shown in diagram on left.

To control only the TIME function:
a. Remove link 10-11 on ITE-51.
b. Connect as shown in diagram on left, EXCEPT omit jumper 9-11 on ITE-51.

To control only the INST function:
a. Remove link 9-10 on ITE-51.
b. Connect as shown in diagram on left, EXCEPT omit jumper 9-11 on ITE-51 and move wire starting at ITE-32Q-(14) from terminal 11 to terminal 9 on the ITE-51.

FIGURE 3 - CONNECTIONS FOR DIRECTIONAL GROUND FAULT PROTECTION (Types ITE-32Q and ITE-51)

APPLICATION DATA

The ITE-32 is a three-phase directional relay, consisting of:

Positive-phase sequence voltage segregating network,
Positive-phase sequence current segregating network, and
One single-phase directional element.

These elements are represented in Figure 4.

SEQUENCE VOLTAGE NETWORK

As shown in Figure 4, the relay is connected to the (delta) voltages, V_{ab} and V_{bc}, through the input transformers. On the secondary side, V_{bc} is phase shifted by 60° lead, and V_{ab} by 0°. These quantities are summed at V_x.

Since $V_a = V_0 + V_1 + V_2$

$$V_b = V_0 + a^2V_1 + aV_2$$

$$V_c = V_0 + aV_1 + a^2V_2$$

and $V_{ab} = V_a - V_b = V_1(1-a^2) + V_2(1-a) = \sqrt{3}V_1 e^{j30} + \sqrt{3}V_2 e^{j330}$

$$V_{bc} = V_b - V_c = V_1(a^2-a) + V_2(a-a^2) = \sqrt{3}V_1 e^{j270} + \sqrt{3}V_2 e^{j90}$$

Then $V_x \sim V_{ab}e^{j0} + V_{bc}e^{j60}$

$$= \sqrt{3}V_1(e^{j30} + e^{j330}) + \sqrt{3}V_2(e^{j330} + e^{150})$$

$$= 3V_1(e^{j0}) + \text{zero}$$

That is, V_x is proportional to the magnitude of the positive- sequence component only.

SEQUENCE CURRENT NETWORK

The relay is supplied with the three-phase currents, I_a, I_b, and I_c through the input transformers. As shown in Figure 4, CTA has a double-wound primary, with I_B wound series opposing I_A. Thus, the secondary current of CTA is proportional to $(I_A - I_B)$. Similarly, the secondary of CTB is proportional to $(I_B - I_C)$. Each secondary is loaded with a resistance R, across each of which appear voltages proportional to these (delta) currents.

The equations for the current network proceed analagous to those for the voltage network, with the conclusion that

$$RI_x \sim RI_1 e^{j0}$$

that is proportional to the positive sequence component only.

DIRECTIONAL UNIT

This is a single-phase unit, polarized with the output of the positive sequence voltage segregating network (V_1). The operating current is the output of the current network, proportional to I_1. Thus, the relay compares the direction of I_1 to V_1.

"Maximum Torque" angle is adjustable from 0 to 90°, that is, I_1 lag V_1 by the selected angle. This relationshipis shown in Figure 5 for settings of 0°, 45°, and 90°. Selection of the angle is made by setting a rheostat on the front panel.

Typical sensitivity curves are shown in Figure 6. Note that these are not product-type relays, and so the minimum operating current is not a function of the voltage. The operation of the relay requires only that the voltage be above the minimum (1V) and the current above the minimum (.02A at the maximum torque angle).

The directional unit is of "block-block" design which requires a timer setting equivalent to 90° (4.16 milliseconds at 60 Hz) for a 180° tripping characteristic. Certain models of the ITE-32 are provided with an adjustable timer which allows setting the timer for a sector width from 30° to 180°. This is illustrated in Figure 7.

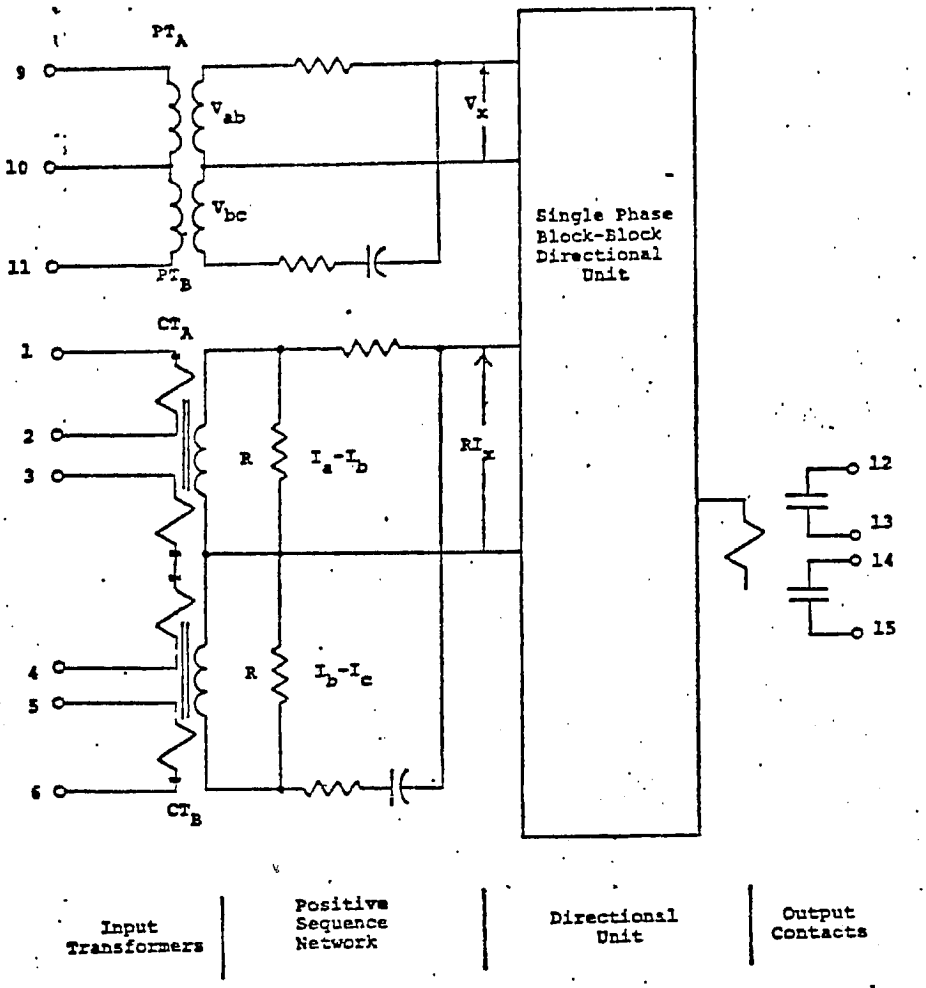
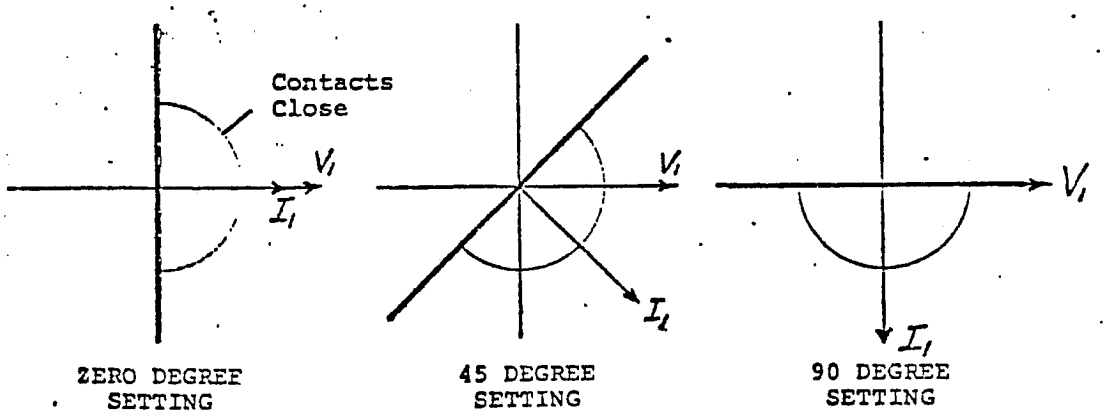


Figure 4: Circuit Description -- Type ITE-32



Positive-Sequence Current I_1 shown at maximum torque position.

Figure 5: Type ITE-32 -- Phasor Diagrams for Various Maximum Torque Angle Settings

APPLICATION

The Type ITE-32 relay is designed for two distinct applications: as the controlling element in directionally controlled time-overcurrent fault protection, or as a high-speed reverse power relay.

LINE PROTECTION

For protection against phase-to-phase, or three-phase faults, the type ITE-32 is used in conjunction with any of the types ITE-51 time-overcurrent relays. Various combinations of controlled time only, or time and instantaneous protection are available by selection of the connections between ITE-32 and ITE-51 units. This combination represents Device Number 67.

Since the ITE-32 compares the direction of the positive sequence current relative to the positive sequence voltage, in certain cases it may be used to provide ground fault as well as phase fault protection. The requirements for this application are that the minimum ground fault current be greater than the phase overcurrent relay setting, and that the ratio of load to ground fault current be greater than three times.

If these requirements cannot be guaranteed, the application requires separate ground fault protection, such as a combination of type ITE-32Q (or ITE-32D), controlling a residually connected type ITE-51. (This combination represents Device Number 67N).

MAXIMUM TORQUE ANGLE

The maximum-torque angle of the relay is adjustable from I_1 lag V_1 between 0 and 90 degrees. 45 degrees is an appropriate setting for most applications. However, in unusual situations, the adjustment of the maximum torque angle may be varied to suit the application. For example, lines operating at high leading power factor angles could cause certain single-phase directional units to pick up undesirably when using the conventional quadrature connection most frequently used with these types. While 45° is probably suitable even for the most highly leading power factor applications, the ITE-32 can be set to accommodate any angle up to 90°.

SECTOR WIDTH

In providing directional control of time-overcurrent relays with instantaneous elements, a hazard always exists in the race between one directional unit dropping out and the instantaneous element picking up. This problem can be avoided by using the ITE-32 with adjustable sector-width.

This application requires setting each of the four 32 relays at each end of the parallel lines (shown in Figure 8), with a maximum torque angle of, say 90°, and a sector width of 90°. As shown, no 32 relay picks up due to load current.

CONNECTIONS

Connections for directional time and instantaneous are shown in Figure 2. For non-directional instantaneous, do not remove the shorting link between 9 and 10, and omit the jumper from 9 to 11. Note that the ITE-51 series of time-overcurrent relays are provided with a standard torque-control option. They are shipped with a link between terminals 9 and 10, to control instantaneous, and a link between 10 and 11 to control time. Removing either link allows control by an appropriate contact.

REVERSE POWER PROTECTION

For reverse power, or anti-motoring protection, the ITE-32 may be used as a sensitive, high-speed, three phase power-directional relay. For these applications, the maximum-torque angle should be set at zero degrees for a watt-characteristic, with line-to-ground, or line-to-line potential transformers, connected as shown in Figure 9.

TYPE ITE-32Q

The Type ITE-32Q is used in conjunction with the ITE-51 to provide directionally controlled time-overcurrent protection against ground-faults. The combination of these two relays performs the function of Device Number 67N.

In construction, the ITE-32Q is virtually the same as the ITE-32, but with different internal connections which change the sequence filters from positive to negative sequence operation.

The ITE-32Q is preferred over the ITE-32D, Dual-Polarized Directional Relay, for protecting lines where incorrect zero-sequence polarization results from mutual induction between parallel lines, or in stations having no zero sequence polarizing quantities.

The ITE-32Q is especially well-suited to switchgear applications since it can be applied with two open-delta potential transformers. This can result in space and dollar savings by eliminating auxiliary potential transformers and compartments.

The ITE-32Q can be used with any of the ITE-51 series of time-overcurrent relays to provide any combination of time-control only, time-and-instantaneous control, instantaneous uncontrolled, or no instantaneous.

Connections for the ITE-32Q and ITE-51 for directionally-controlled time-overcurrent ground-fault protection are shown in Figure 3.

The phasor diagrams for Type-32Q are shown in Figure 10.

Note that the maximum torque angle of the ITE-32Q is equal to 180 degrees minus the front panel dial setting.

RATINGS

Temperature	
Operating Range	-30°C to +70°C
Input Circuit Ratings	
Potential	120V, nominal 160V, maximum continuous
Current	5A, nominal 16A, maximum continuous 390A, one second
Burden	
Potential	0.3VA, per phase, at 120V
Current	1VA, phases A and C at 5A 2VA, phase B at 5A
Sensitivity	.02A at 1.0V, .02A at 120V
Maximum Torque Angle (Adjustable)	Type ITE-32: 0 to 90°, I_1 lag V_1 Type ITE-32Q: 90 to 180°, I_2 leads V_2 (Front-Panel Settings of 90° and 0° respectively.)
Control Power	Refer to nameplate for rated control voltage. Battery drain approximately 0.050 amperes
Operating Time	
Pickup	Less than 1 cycle, 60 Hz
Dropout	Less than 1 cycle, 60 Hz

Output Circuit Rating

Units with Tripping Contacts
@ 125Vdc
30 amps, Tripping
5 amps, Continuous
1 amp, Opening Resistive
0.3 amp, Opening Inductive

Other models available specifically for controlling ITE-51, ITE-50H, ITE-50D Overcurrent Relays.

CATALOG NUMBERS AND CHARACTERISTICS

Type ITE-32

Maximum Torque Angle	Sector Width	Sensitivity	Control Voltage	Contacts	Frequency	Catalog Number
Adjustable 0 to 90° I_1 lag V_1	180°	0.02A at 1V	48/125Vdc	①	60Hz	225P0070
			48/125Vdc		50Hz	225F0070
			250Vdc		60Hz	225P0050
			250Vdc		50Hz	225F0050
	$\frac{30°-180°}{180°}$		48/125Vdc		60Hz	225P0071
			48/125Vdc	②	60Hz	225P0073
			48/125Vdc		50Hz	225F0073
			24Vdc		60Hz	225P0093
		0.4A at 1V	48/125Vdc		60Hz	225P0176

Type ITE-32Q

Maximum Torque Angle	Sector Width	Sensitivity	Control Voltage	Contacts	Frequency	Catalog Number
Adjustable 90° to 180° I_1 lag V_2	180°	0.02A at 1V	48/125Vdc	①	60Hz	225Q3070
			48/125Vdc		50Hz	225J3070
			250Vdc		60Hz	225Q3050
			250Vdc		50Hz	225J3050
	$\frac{30°-180°}{180°}$		48/125Vdc		60Hz	225Q3071
			48/125Vdc	②	60Hz	225Q3073
		0.4A at 1V	48/125Vdc		60Hz	225Q3176

Notes:

① This model preferred when directional relay will be used to control an ITE-51, as in directionally controlled overcurrent relay schemes.

② This model required when directional relay will be used to operate lockout relay or trip circuit breaker, as in reverse power schemes. When specified, a normally closed contact between terminals 15 and 16 will be supplied in addition to the standard (2) normally open contacts. When wiring to terminal 16, observe proper clearance of the wire termination to the ground stud terminal "G".

For additional information see CONNECTIONS, Page 3.

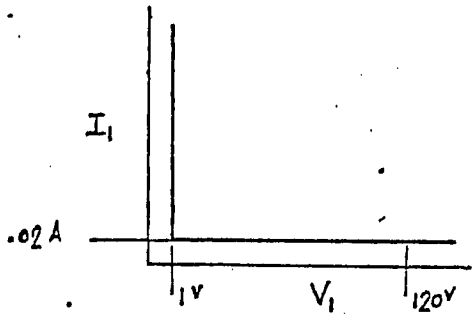


Figure 6: Sensitivity
0.02 amp models

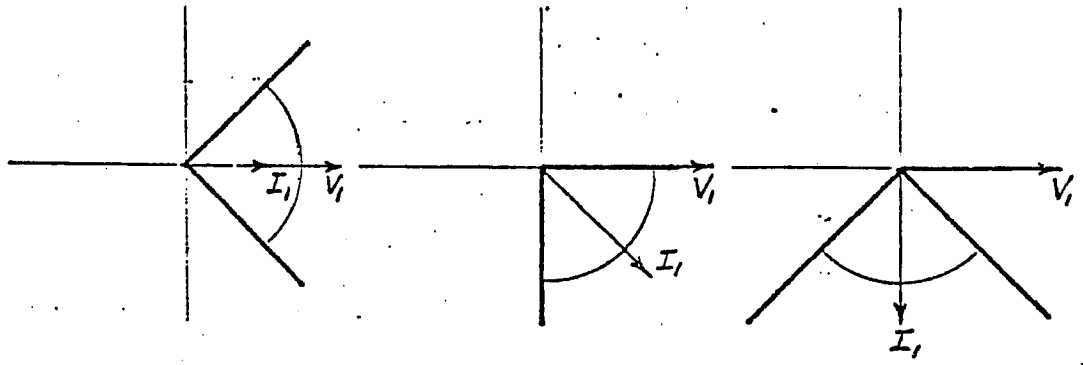
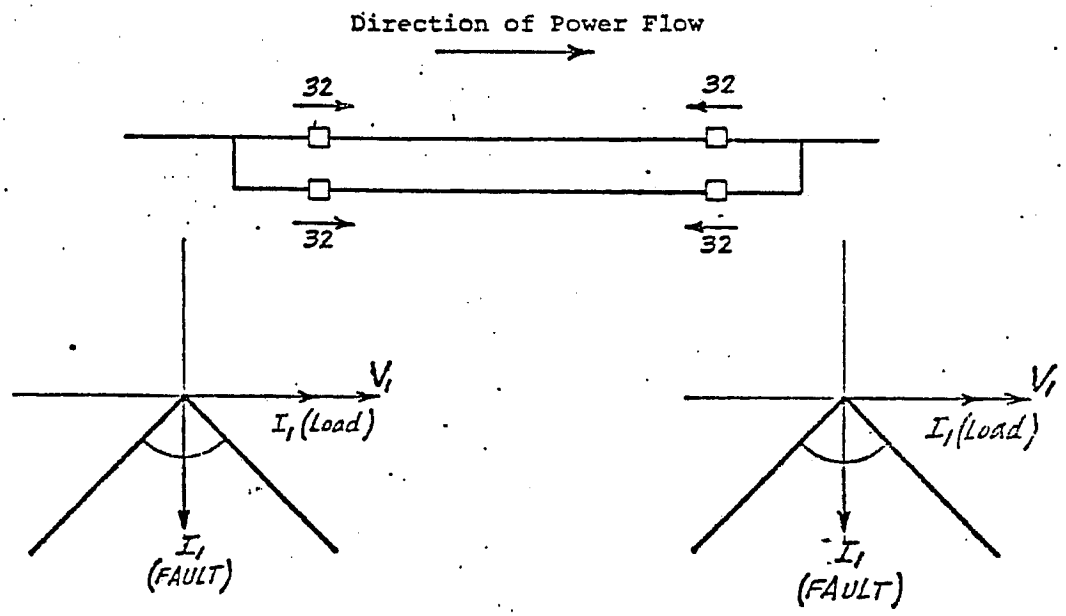


Figure 7: Sector Width Adjusted to 90° in Each Case.



Phasors for Load and Fault at each end of Line Positive Direction of current assumed into the line at each end.

Figure 8: Type ITE-32 -- Parallel Line Protection

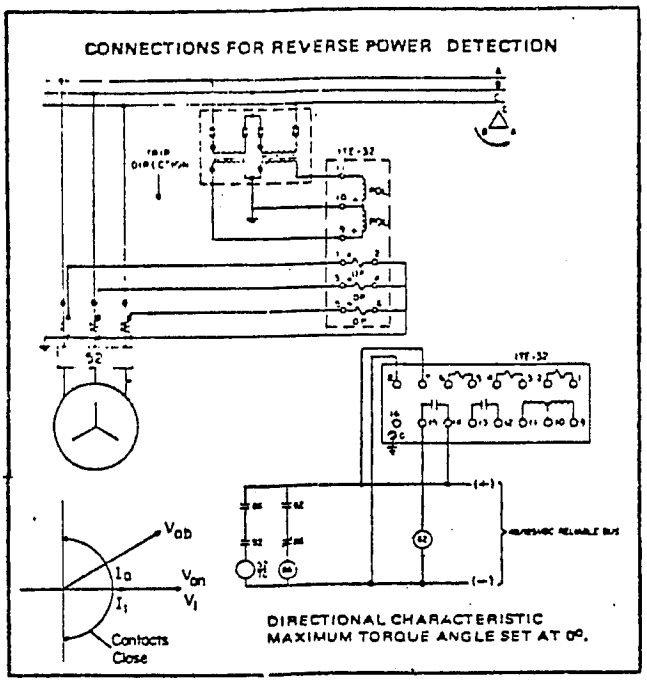


Figure 9: Type ITE-32
Connections for Reverse Power Detection

Timer (device 62) Recommended to prevent nuisance operations.

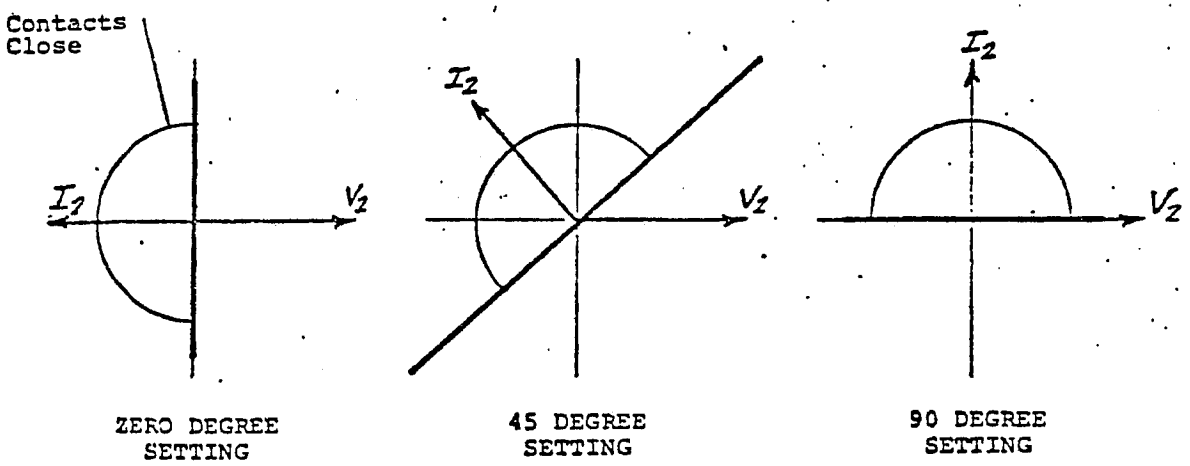


Figure 10: Type ITE-32Q -- Phasor Diagrams for Various Maximum Torque Angle Settings

TESTING

1. MAINTENANCE AND RENEWAL PARTS

No routine maintenance is required on the relay. Follow test instructions to verify that the relay is in proper working order. If a relay is found to be inoperative, we suggest you return it to the factory for repair. However, by specifying the relay's catalog number, a schematic and circuit description may be obtained through your Gould-Brown Boveri sales engineer should you desire to attempt repair yourself.

These relays have a control relay as the output stage. This output relay may be ordered from the factory. When ordering, state the type relay, catalog number, and serial number.

Also available from the factory are circuit card extender boards. This relay requires the 18 point board, catalog 200X0018.

Drawout Element

Drawout-circuit boards of the same catalog number are interchangeable. The board is removed by using the metal pull knobs on the front panel. The relay is identified by a catalog number on the front panel and a serial number on the underside of the circuit board.

2. HIGH POTENTIAL TESTS

Do not apply high voltage tests to solid-state relays. If a control wiring insulation test is required, bond all terminals together and disconnect grounding wire before applying test voltage.

3. ACCEPTANCE TESTS

Mounted in Switchgear

Tests should be made on a de-energized main circuit. If tests are to be made on an energized circuit, be sure to take all necessary precautions.

The ITE-32 and ITE-32Q are equipped with a built-in operational test. With control power applied, and no current applied, or current in the non-trip direction, depress the TEST button. A "trip direction" condition will be simulated and the relay should operate. A target will be displayed or, on units with LED indicators, the LED will light. Caution: if the directional relay is wired to torque-control an ITE overcurrent relay, and load current above the pickup setting of the overcurrent relay is flowing, the overcurrent relay will also trip, after the appropriate time delay.

Caution: the TRIP test buttons on the ITE overcurrent relays bypass the torque-control function; therefore, in a directionally controlled scheme, depressing the TRIP button will cause the overcurrent relay to trip (after the appropriate time delay) regardless of the state of the controlling contact.

For directionally controlled overcurrent relay schemes the meter unit of the ITE X51C Overcurrent Relay Test Accessory may be used to observe the operation of the directional relay contacts when the relays are in service. See Instruction Book 18.2.7-4 for procedures.

ITE-32 TESTING PROCEDURE

a. It is very difficult to measure the phase angle between the positive sequence voltage and current, therefore, it is desirable to measure the phase angle between I_A and V_{AB} and subtract the inherent 30^o difference. (Angle that V_{AB} leads I_A)

b. Connect the ITE-32 relay as shown in Figure 11.

c. Set the desired MAX TORQUE ANGLE on the front panel.

d. Vary the phase angle to determine the range of operation of the relay.

FIGURE 11 ITE-32 TEST CONNECTIONS