INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE HKB CARRIER RELAYING
WITH TYPE FD CARRIER EQUIPMENT

INTRODUCTION

The high-speed clearing of faults on transmission lines is recognized as necessary for good system operation. The best overall protection is provided by the method known as differential relaying in which conditions at the two ends of the line are compared to determine whether the fault is in the line section or external to the protected zone. This assures simultaneous tripping of the breakers, which is desirable from the standpoints of stability, continuity of service, quick reclosing, and minimum damage to equipment. For many lines, carrier relaying is the most practical and reliable medium for comparing the conditions at the two ends of the line.

The type HKB system of carrier protection uses a single relay operation (on current only) at each end of the transmission line section to detect and determine the location of faults. It compares over a carrier pilot channel the phase angle between currents at the two ends of a line section to determine whether an internal or external fault exists.

A positive, negative and zero sequence current filter is used to obtain a single-phase voltage from the three-phase line currents, and this voltage is utilized to energize fault detectors and to control the transmission of alternate half cycle blocks (at the power frequency) of carrier energy from both ends of the line section.

The carrier signal from each end is received at the opposite end of the line where it is rectified, and compared with the phase position of the output voltage of the local sequence filter. This comparison takes place in a vacuum tube. The polarity of the filter and carrier voltages is such that no current flows in the vacuum tube plate circuit for a fault external to the protected line section when the line currents are exactly in phase at the two ends. For an internal fault with the currents at the two ends of the line 180° out-of-phase, plate current will flow on alternate half-cycles of the line current frequency. This plate current flows through a transformer primary winding, and the a-c voltage developed on the secondary side is rectified and supplied to a relay whose contact is in the trip circuit. The voltage in the transformer secondary is sufficient to trip the relay for an internal fault. This arrangement thus provides simultaneous tripping over the entire line section for all faults within the settings of the relay. As this system operates on line current only, it is not subject to tripping on power swing or out-of-synchronism conditions since the circulating currents appear to the relays as an external fault. If tripping is desired on an out-of-synchronism condition, auxiliary relays must be added for this purpose. For an internal fault on a line fed from one end only, tripping will occur at the terminal through which fault current is flowing into the line section.

COMPONENTS OF COMPLETE EQUIPMENT

An outline of the equipment used at each terminal of a transmission line section is as follows:

1. One type HKB relay which includes the sequence filter, fault detectors to start the transmission of carrier and control the operating element (tripping

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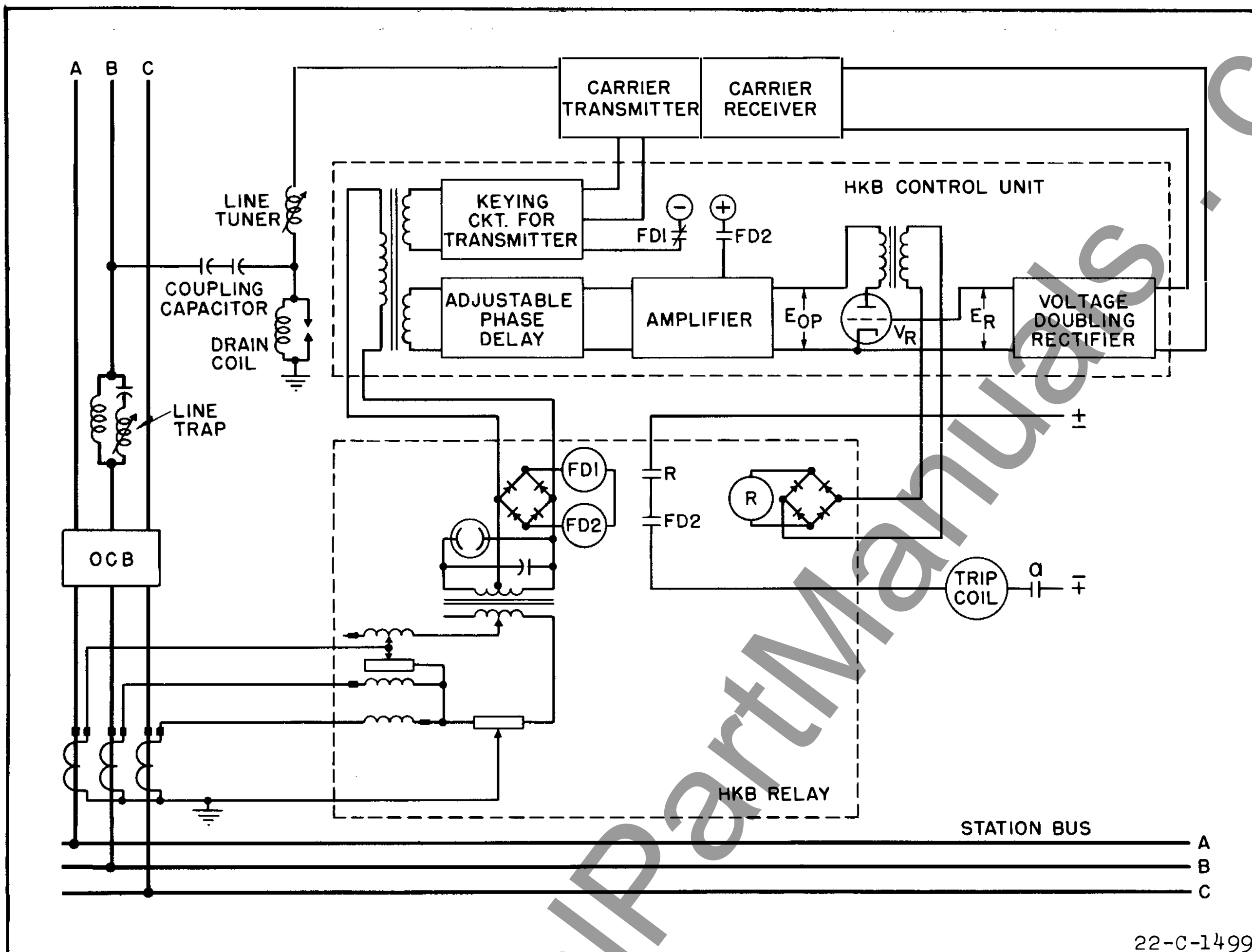

Fig. 1—Basic Schematic Connections of the Type HKB Relaying System.

relay), and the operating element itself.

2. A d-c operated, type FD carrier transmitter-receiver which also includes a type HKB Control Unit. The control unit is energized from the output of the relay sequence filter, and has three functions, as follows:

   a. To control the transmission of half cycle blocks of carrier.
   b. To rectify the received half cycle blocks of carrier from the distant transmitter.
   c. To compare the phase position of the received carrier and the local sequence filter output to determine whether or not the relay should trip the breaker.

3. A coupling capacitor with carrier auxiliary for introducing the carrier frequency on to the transmission line. This may be supplied with a potential device for obtaining line-to-ground potential for synchronizing or 3 sets used for measuring 3-phase line potential. The carrier coupling capacitor is the type PC, and with the potential device, is the type PCA. The line potential is not required for the type HKB relay.

4. A Line Coupling Tuner. This unit is used to tune out the capacitive reactance of the coupling capacitor and match the transmitter or receiver circuits to the transmission line. The tuner may be part of the carrier assembly when the transmitter-receiver is mounted outdoors. It is usually sepa-

rately mounted near the coupling capacitor when the transmitter-receiver is located indoors some distance from the tuner.

5. A Line Trap to prevent short circuiting the carrier transmitter output during a nearby external ground fault on the same phase wire to which the carrier is coupled.

Similar equipment is required at each line terminal of the protected line section. Each line section is considered as a unit and should be assigned a different frequency to minimize the possibility of interference with other lines.

The transmitter-receiver sets are tuned to respond to the assigned frequency so that either receiver may receive a signal from the transmitter at the opposite end of the section. It is not necessary for the receiver to receive a signal from its own transmitter, since the carrier signal from each terminal serves only to block tripping at the opposite terminal for an external fault. Therefore, it is possible on two terminal lines to use two frequencies in this carrier scheme and obtain two independent carrier channels for transmitting auxiliary functions in two directions simultaneously.

OPERATION OF SCHEME

Fig. 1 shows a complete basic diagram of one terminal of the relaying system. The three-phase line currents energize the sequence filter. The single-phase output of the sequence filter is connected to two fault detectors (FD1 and FD2) and to the input circuit of the control unit. The fault detectors are used to obtain an intermittent carrier scheme, and are usually set above load current so that the carrier channel is available for any auxiliary function such as communication or telemetering except during the time of a fault.

Fault detector FD1 is set to operate at the relay tap value, and allows the control unit circuits to send out half-cycle blocks of carrier and provide operating voltage. Fault detector FD2 is set to trip 25 percent above tap value, and supervises the operation of the tripping relay element R through the relay tube. Thus, tripping of the line breaker cannot occur until FD1 and FD2 have both picked up. The 25 percent margin between them is to insure that the carrier start fault detectors (FD1) at both terminals of a line will pick up on a remote external fault before the relay tube is energized, through FD2 to insure correct blocking. Under a condition of temporary overload on the line, the fault detectors may pick up and operate the relaying system continuously. During such a time, the carrier channel is not available for any auxiliary function.

Upon the occurrence of a fault, the contact of the fault detector FD1 opens and removes negative voltage from the carrier keying circuit. This causes the transmission of carrier on alternate half-cycles of the power frequency. Another winding on the control unit input transformer energizes a phase-shifting network and a 60-cycle amplifier. The phase shifter is adjustable and is set to compensate for delay on the transmission line or in the channel equipment. The amplifier increases the sequence network output to a suitable value for plate voltage (operating voltage) on the relay tube V_R.

The carrier receiver output energizes a voltage-doubling rectifier which provides a negative bias (restraining voltage) on the grid of the relay tube V_R whenever carrier is transmitted from the remote terminal (or from the local terminal with single frequency carrier). The magnitudes of the operating and restraining voltages are such that plate current will flow in the relay tube V_R with positive plate voltage but no restraining voltage on its grid. When restraining voltage is present, V_R plate current is blocked. The carrier transmitter and receiver are conventional carrier relaying units whose construction and principle of operation are well known.

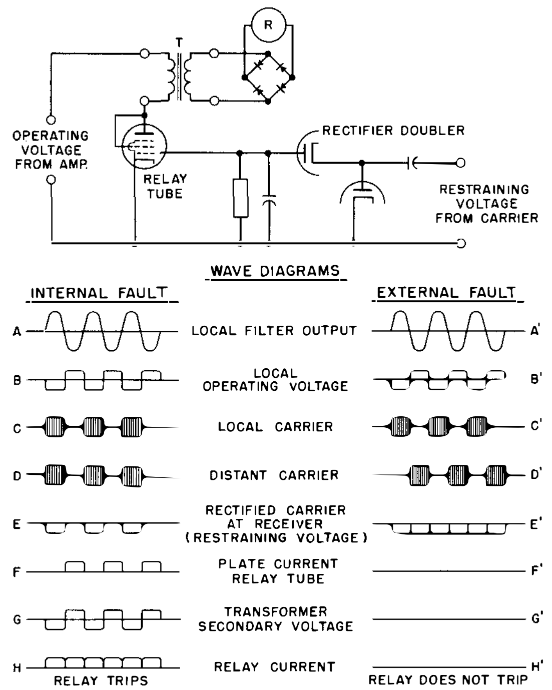

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Fig. 2—The Relay Tube Circuit and Typical Wave Diagrams of the Type HKB System.

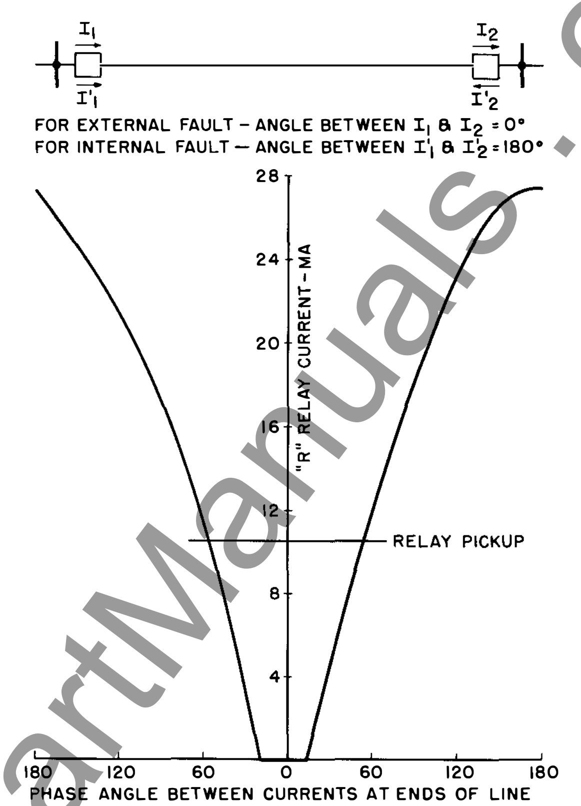

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Fig. 3—Typical Overall Characteristics of the Type HKB System.

Response To Faults

Fig. 2 shows in detail how the circuits just described determine whether an internal or external fault exists. The relay tube circuit is shown at the top of Fig. 2 for convenience. The "operating voltage from amplifier" is the voltage E_{op} of Fig. 1. It is called operating voltage, as it makes the plate of the relay tube positive on alternate half-cycles, causing the flow of relay-tube plate current. The "restraining voltage from carrier" is the d-c output E_R of the voltage-doubling rectifier and is so named as it opposes the operating voltage and prevents the flow of plate current in the relay tube by applying negative potential to its grid.

To see how the quantities shown in Fig. 2 are utilized,consider first an internal fault. The polarities of the sequence-filter -output voltages at the two ends of the line are such that, when the fault detectors operate, carrier is transmitted from both line terminals on the same half-cycles (Fig. 2, C and D). The received and rectified carrier restraining voltage (Fig. 2, E) is applied to the grid of the relay tube.

For an internal fault, there is no rectified carrier voltage druing the half-cycles that the plate of the relay tube is made positive by the operating voltage. As a result, plate current will flow in the relay tube, as shown at F in Fig. 2. The half-cycle plate-current pulses flow through the primary winding of the transformer T. The secondary voltage (Fig. 2, G) is rectified to provide a steady relay operating force, and the direct voltage so obtained causes current to flow to operate the relay **R** (Fig. 2, H).

During an external fault, when the fault detectors pick up, carrier is transmitted from the two ends of the line on alternate half-cycles as shown at C' and D' in Fig. 2. This change occurs because the current at one end of the line has reversed with respect to the current at the opposite end. If the current entering the line is in phase with the current leaving it, the rectified carrier at each receiver will provide a substantially continuous restraining voltage (Fig. 2, E'). As a result no plate current flows (Fig. 2, F') and the relay does not operate.

The phase position of the line current theoretically may fall anywhere between the in-phase position and the 180 degree out-of-phase position. Fig. 3 shows the characteristics of the relay over this entire range. As the phase position changes from in-phase (external fault) to out-of-phase (internal fault), the blocks of the distant carrier change in phase position with respect to the blocks of local carrier, the two extremes being shown in Fig. 2, C and D, Fig. 2, C' and D'. Between these two extremes the plate current of the relay tube will be blocked over more and more of the cycle, and the rms value of the A-C component of the plate current will decrease.

This will result in a decrease of the current in relay R as shown on the typical phase angle relay-current relationship Fig. 3. By adjusting the sensitivity, the relay R can be set to operate when the angle between the currents at the two ends of the line becomes any desired value, such as 55 degrees, as shown.

The preceding explanation is based on single frequency operation of the carrier equipment. That is, the transmitters and receivers at both ends of the line are tuned to the same carrier frequency. It should be noted, however, from a comparison of Fig. 2, B and C, that carrier is transmitted locally only on the half-cycles when there is no positive operating voltage present. Consequently, it is never necessary to receive the local carrier signal, since the relay-tube plate current always will be zero during these half-cycles. This means that two-frequency operation of the carrier transmitters and receivers is possible without complication, if it is desired to use some auxiliary function which requires a two-frequency channel. In two-frequency operation, the transmitter at one end of the line and the receiver at the opposite end are tuned to one carrier frequency, and the other transmitter and receiver are tuned to a different frequency. This permits simultaneous transmission and reception in both directions as would be needed for telemetering in one direction and load control in the opposite direction.

This relaying system will operate correctly for faults with an uneven distribution of current from opposite line terminals. Consider an internal fault which picks up both fault detectors (FD1 and FD2) at one line terminal (#1) but only FD1 at the opposite terminal (#2). Tripping cannot occur at station #2 because FD2 is not picked up. However, picking up of FD1 will transmit the half-cycle blocks of carrier of the proper phase position which will still allow high-speed tripping at station #1.

After the breaker at station #1 has tripped, redistribution of the fault current may pick up FD2 at station #2 in which case it will trip in a high-speed sequential tripping operation.

Provision for Checking Operation

It is desirable to check periodically the condition of the carrier set to determine its ability to send and receive a carrier signal. For this purpose a test push button is connected in parallel with the auxiliary carrier start elements. Pressing the test push button sends a carrier signal which is received by the receiver to operate an alarm relay and energize a milliammeter. If the carrier set is not functioning, the alarm is not heard and the milliammeter does not deflect, indicating trouble which must be investigated. The alarm relay has a minimum operating value in excess of the minimum required to block the relay tube so that an indication of impending trouble can be obtained before actual failure

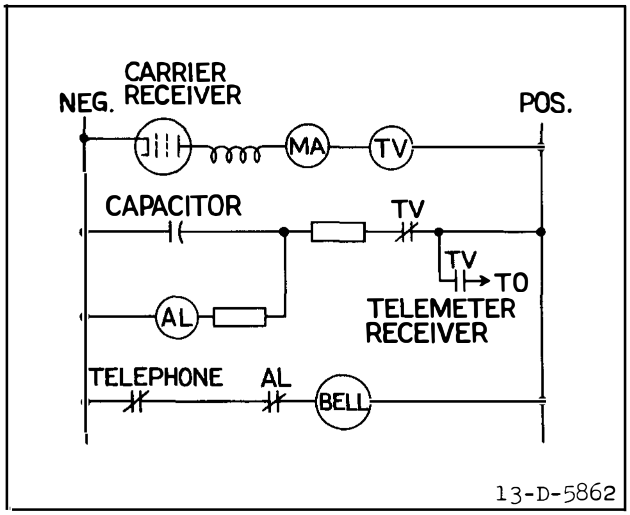

Fig. 4—Time Delay Circuit for the Carrier Alarm when using the Carrier Channel for Telemetering or Supervisory.

occurs.

Operation of the HKB relaying system for all faults is dependent upon correct functioning of the electronic components as well as the HKB relay itself. To provide a simple manual test of the entire installation, a test transformer and test switch are provided. With this equipment, faults are simulated by applying a single phase current to the HKB relay at both ends of a line section. By reversing the polarity of the test current at one station, both internal and external fault response can be checked. Indicator lamps show when the trip circuit is completed for an internal fault. During the test, the trip circuit to the line circuit breaker is opened. The test switch for this test is also used as a carrier on-off switch. Turning it to the "off" position removes carrier relaying and leaves the line protected by the backup relay.

ADDITIONAL USES FOR CARRIER CHANNEL

In addition to relaying described above, the carrier channel can be used for other functions such as telemetering, load control, communication, supervisory control and remote tripping. For these functions, a separate lead is brought out from the transmitter to start carrier. This arrangement provides independent keying contacts or circuits for relaying and the other functions. In the event of a fault, operation of fault detector FD1 interrupts the auxiliary function and allows the relay to control carrier. This preferential use of carrier will occur during a fault only if there is a sufficient source of power at all terminals to pick up the protective relays.

There may be times when the relay is unable to take control of the carrier. An example is the case where no fault current flows at one end of the line. Here a telemetering impulse or telephone conversation could prevent tripping, because there would be no relay operation at the zero-current terminal to interrupt the carrier. However, even this condition can be taken care of by the use of under-voltage fault-detector relays connected to a line-side potential source. The contacts of the under-voltage relays are connected in the auxiliary carrier start circuit so that if one or more relays drop out during a fault, the auxiliary-function carrier signal will be interrupted, thus allowing the opposite terminal to trip.

Another possibility is to energize the auxiliary carrier-start circuit through a breaker "a" switch. By doing this, the carrier signal for telemetering or communication will be stopped whenever the breaker is open. This will allow tripping of the other terminal for a fault on the line section when one breaker is open. However, if continuous telemetering is required whether the breaker is open or closed, then undervoltage relays must be used as described in the previous paragraph.

In order to prevent the carrier alarm from ringing during the time carrier is being used for auxiliary telemetering function, the time delay circuit of Fig. 4 can be used at each terminal. This circuit consists of a combination of resistors and a capacitor energized through contacts on an auxiliary Type TV relay. When telemetering impulses are being sent or received, the coil of the Type TV relay in the receiver plate circuit is energized on each impulse. This causes the normally closed contact, TV, to alternately open and close energizing the circuit thru a resistor and a capacitor. In parallel with this capacitor is a circuit consisting of a resistor and the coil AL of the carrier alarm element. The resistors and capacitor are chosen so that for this particular case a maximum relay of approximately 2 seconds are obtained. This will prevent operation on the longest telemetering impulse.

If it is desired to signal by means of the push button, it is only necessary to hold the push button closed for a period long enough to cause the alarm element to drop out. Energizing carrier thru the push button maintains the normally closed contact (TV) open and when the charge on the capacitor is used up the alarm element will drop out, closing its back contact marked "alarm" and causing the bell to sound. By properly proportioning the resistor and capacitor, a wide range of drop-out times can be obtained for the alarm element.

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