OPERATION OF SCHEME

INSTRUCTIONS

TYPE HKB CARRIER RELAYING

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 operating (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 the grid circuit of a vacuum tube which is so biased that no plate current flows when there is no filter or carrier voltage on its control grid. 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

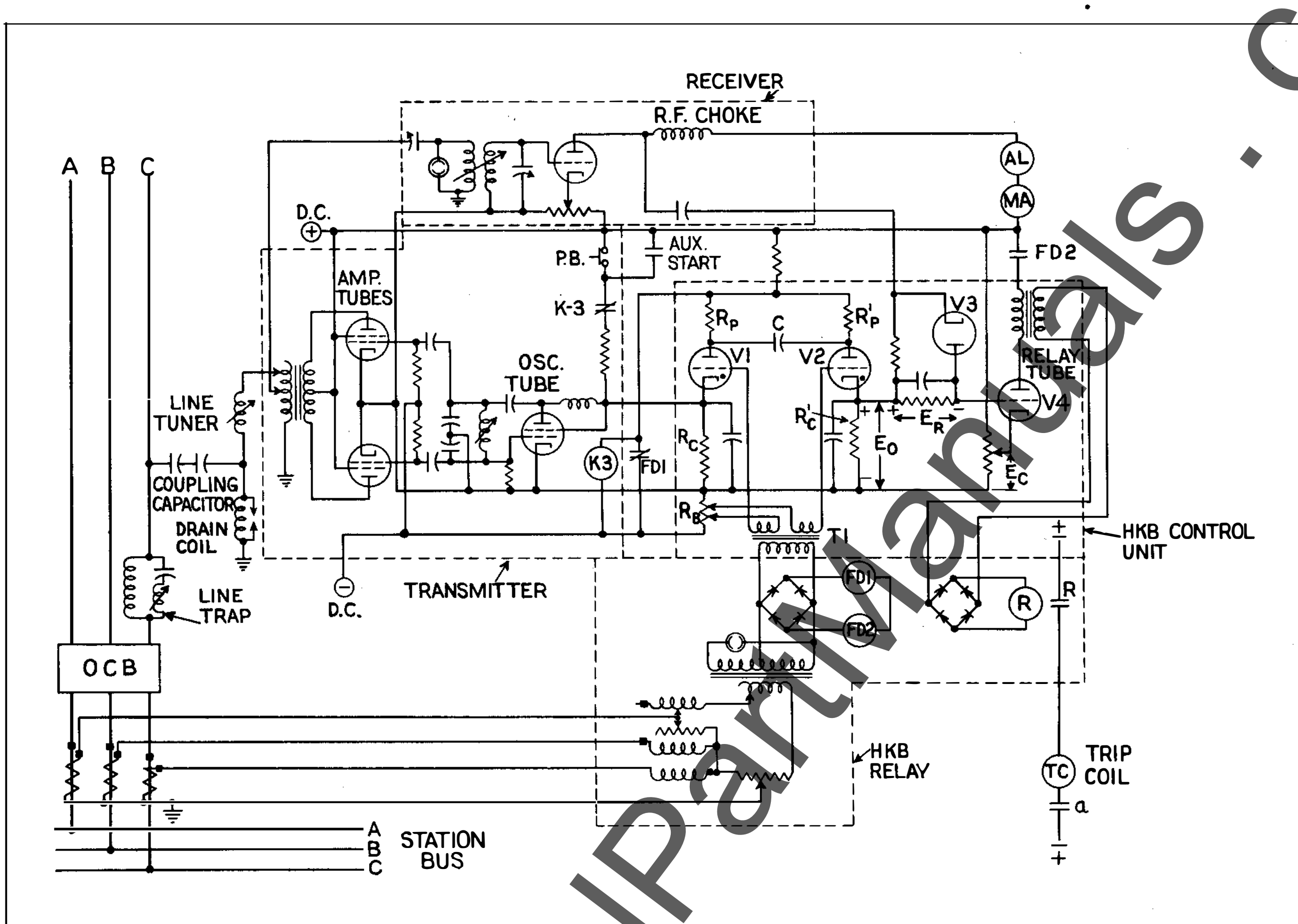

Fig. 1—Basic Schematic Connections Of The Type HKB Relaying System.

relay), and the operating element itself.

2. A d-c operated, type JY 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 set when the transmitter receiver is mounted out doors. It is usually separately 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. These are usually the type P, such as types P-400, P-800, PDF-400 and PDF-800.

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

Figure 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 grids of two thyratrons V1 and V2 through a transformer T1. These thyratrons and associated resistors and capacitors comprise a trigger circuit which is operated by the filter output voltage. 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 trip at the relay tap value, and allows the trigger circuit to operate sending out half cycle blocks of carrier and providing 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. This 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 applies positive direct voltage to the plate circuits of V1 and V2. When the grid of V1 becomes positive, as a result of the filter output voltage, it fires and its plate or anode current very rapidly rises to a steady-state value as determined by the supply voltage and the plate and cathode resistors (Rp and Rc) of the tube. On the next half cycle, the grid of V2 becomes positive, and thyratron V2 fires. When this occurs, the charge on the capacitor C, connected between the plates V1 and V2 make the plate potential of V1 momentarily negative which extinguishes V1. Thus, the wave form of plate current on either thyratron will be square half-cycles of fixed magnitude for any value or wave form of grid voltage providing, of course, sufficient grid voltage is present to fire the thyratrons V1 and V2. The voltage drop across the V1 cathode resistor Rc is used as the plate-supply voltage for the oscillator tube in the carrier transmitter. Applying this voltage to the plate of the oscillator causes the transmission of carrier on alternate half-cycles of the power frequency.

The voltage (Eo) across the other cathode resistor Rc of thyratron V2 is connected in the grid circuit of the relay tube V4 in series with the rectified output (ER) of the carrier receiver as shown. When V2 fires, the voltage drop across R'c makes the grid of the

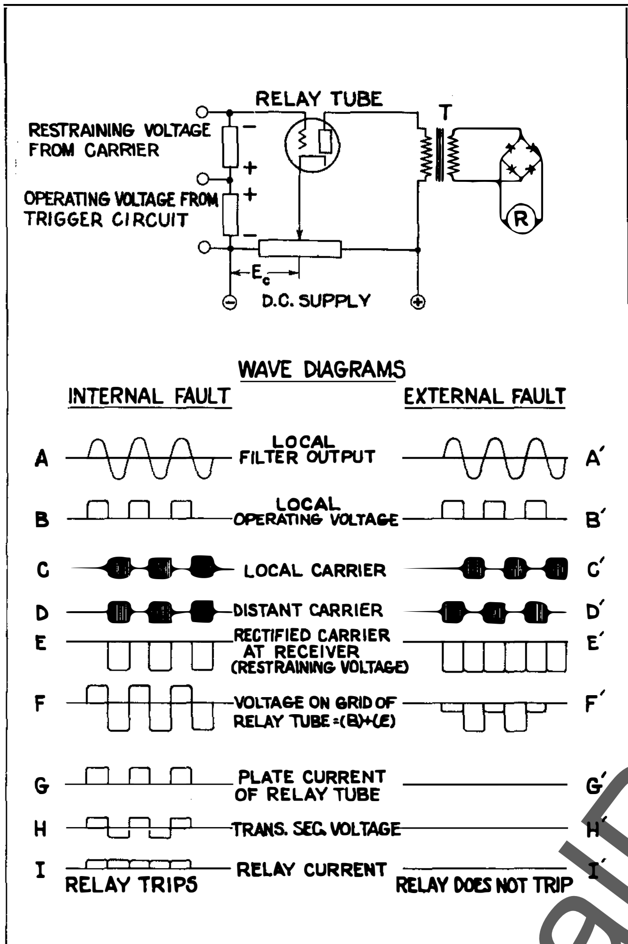

Fig. 2—The Relay Tube Circuit and Typical Wave Diagrams Of The Type HKB System.

relay tube positive. The rectified output of the carrier receiver is connected with the opposite polarity and is sufficient to cancel the effect of the voltage across R'c if carrier is received at the same time that V2 is conducting. The voltage drop across resistor RB provides negative grid bias for the thryatrons. The carrier transmitter and receiver are conventional carrier relaying units whose construction and principle of operation are well known.

Response To Faults

Figure 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 Figure 2 for convenience. The "operating voltage from trigger circuit" is the voltage drop Eo across

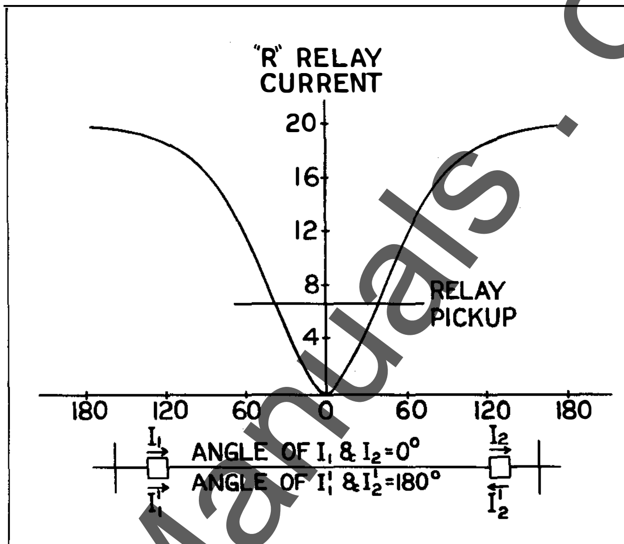

Fig. 3—Typical Overall Characteristics of the Type HKB System.

R'c of Figure 1. It is called operating voltage, as it makes the grid of the relay tube positive, causing the flow of relay-tube plate current. The "restraining voltage from carrier" is the d-c output ER of the carrier receiver 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 Figure 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 (Figure 2, C and D). The received and rectified carrier restraining voltage (Figure 2, E) is applied to the grid of the relay tube in series with the operating voltage (Figure 2, B). The net voltage on the grid of the relay tube is the sum of these two voltages, and has the wave form indicated at F on Figure 2.

The reference axis at F is the voltage E_c required to cut off the plate current of the relay tube. Consequently, when the net grid voltage is above this axis, plate current flows. For an internal fault, there is no rectified carrier voltage during the half-cycles that the grid 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 G in Figure 2. The half-cycle plate-current pulses flow through the primary winding of the transformer T. The secondary voltage (Figure 2, H) is rectified to provide a steady relay operating force, and the direct voltage so obtained causes current to flow to operate the relay R (Figure 2, I).

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 Figure 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 (Figure 2, E'). This voltage in series with the operating voltage (2, B') gives a resultant value which is always more negative than the cutoff bias of the relay tube (Figure 2, F'). As a result no plate current flows (Figure 2, G') 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. Figure 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 Figure 2, C and D, Figure 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 Figure 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 35 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 Figure 2, B and C, that carrier is transmitted locally only on the half-cycles when there is no 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.

It is desirable to check periodically the condition of the carrier set to determine its ability to send and receive a carrier signal.

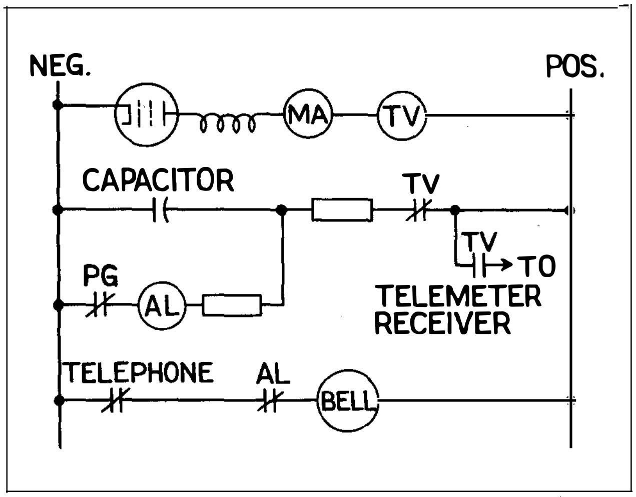

Fig. 4—Time Delay Circuit For The Carrier Alarm When Using The Carrier Channel For Telemetering or Supervisory.

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 tubes at both ends of the line section 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 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. Fore these functions, a separate lead from the oscillator plate circuit is brought out through a back contact K3 to the auxiliary start contacts as shown in Figure 1. This arrangement provides independent keying contacts for relaying and the other functions. The K3 relay coil is energized by the carrier start fault detector contacts (FD1) to open up the auxiliary start contact in order to allow triggering of the thyratrons.

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 Figure 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.

The alarm bell can be made to operate instantaneously whenever the relays start carrier by using the type PG relay connecting in the carrier relay start circuit with its back contact in the alarm coil circuit.

Emergency point-to-point communication is normally supplied with the carrier relaying equipment. This can be done by plugging a hand-set at the carrier set, at the relay switchboard or from a desk set permanently wired to the equipment. The push-to-talk type of communication is employed where the operator pushes a switch on the handset to start carrier and connect the microphone to the carrier transmitter. During the listening period, the operator releases the switch. Whenever the handset is plugged in or lifted from the desk stand, the carrier alarm circuit is opened to prevent ringing during the conversation. This alarm circuit is used for code ringing.

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