CONSTRUCTION

LCB II

The Type LCB II Relay is mounted on a 19-inch wide panel, 5.25 inches high (3 rack units) with slotted edge holes for mounting on a standard relay rack or panel. For the outline and drilling plan, refer to Fig. 12.

The removable front cover has a smoked plexiglass front for viewing of the LED indicators on the various enclosed modules. Two holes in the cover provide accessibility for the dc input power on/off and system indicator reset switches. The front cover is removable with two thumb screws, which also have a hole for sealing if desired.

The rear panel consists of seven 8 point terminal blocks for making all external connections. Screw size is 6-32 and can handle wire sizes from No. 10 to 30 AWG with appropriate lugs. Ground studs are also available on the rear panel for system grounding. A cutout exists in this panel for access to fiber-optic connectors on the fiber-optic interface modules (when used).

Inside the rear panel, the terminal blocks connect to a circuit board comprised of surge capacitors connected from the terminal to ground, for those leads exposed to the switchyard environment. These capacitors provide the necessary protection from external surges. Between this rear panel and the rear of the module enclosure, the LCB is prewired for all possible available options.

All of the circuitry associated with the LCB operation and suitable for mounting on printed circuit boards is contained in the enclosure behind the front cover. The printed circuit modules slide into position in slotted guides at the top and bottom of the enclosure and engage a printed-circuit connector at the rear of the compartment. Each module and connector are keyed so that they cannot be accidentally inserted into the wrong slot location. Handles and a front plate on the modules are used for identification of the module name and location, indication description, module removal and insertion and as a bumper with the front cover to prevent the terminals from accidentally becoming disconnected from the terminal connector. The modules may be removed for replacement purposes or for use in conjunction with a module extender, Type UME-3, Style 1447C86G01, which permits access to the module's test points and terminals for making measurements while the relay is energized.

All components used in the LCB are completely tropicalized.

TEST PANEL

The optional LCB test panel is mounted on a 19-inch side panel, 5-1/4 inches high (3 rack units) with slotted edge holes for mounting on a standard relay rack or panel. For the outline and drilling plan refer to Fig. 13. This unit consists of 2 type FT-1 10 terminal FT switches and is used to provide interface between the LCB and the power system for such inputs as the current transformer, dc battery, trip circuits and breaker control. Four resistors and a pushbutton are included to simulate breaker trip coil current. Fuses are provided for ac voltage.

AUDIO-TONE PROTECTION PACKAGE

The optional audio-tone protection package is mounted on a 19-inch wide panel, 3.5 inches high (2 rack units) with slotted edge holes for mounting on a standard relay rack or panel. For the outline and drilling, refer to Fig. 14. Mounted behind the panel are 600 ohm isolating/matching transformers and resistor/zener surge protectors. Connection from the pilot pair and LCB tone output is made via terminal blocks at the rear of the panel. Test jacks on the front panel are available for facilitating measurements of the incoming and outgoing tone levels.

PORTABLE TEST BOX (UCTB)

The test box is built to be portable with rubber feet on the bottom or it can be mounted on a 19-inch wide relay rack or panel by means of two thumb screw latches on each side. The height of the unit is 5.25 inches (3 rack units). When mounted in the rack by means of the latches, the bottom should be supported with a steel bracket.

A 6-foot harness and grounding wire comes with the test box to provide connection between the box and test panel.

The UCTB contains an isolating step-down transformer, loading resistors, FT-1 switch and two rotary switches, one for fault selection and one for fault application.

Outline of the UCTB is shown in Fig. 15.

OPERATION

SYSTEM OPERATION

The essential elements of the relay are shown on block diagrams Figs. 4 and 5, audio-tones, 2 and 3-terminal lines, and Figs. 6 and 7, fiber-optics, 2 and 3-terminal lines. The 3-phase currents are transformed to voltages which are then combined into a representative single-phase voltage by means of the sequence filter. This active solid-state circuit produces a precise, repeatable output as a function of the 3-phase current load or fault conditions. The relative amount of positive (P), negative (N), and zero (Z) sequence may be adjusted independently to best match power system conditions. The only data required for calculating settings are minimum 3-phase fault current from the strongest terminal, minimum phase fault current from the strongest terminal, and maximum expected load current. (Ref. SETTINGS Section.)

The output of the sequence network is simultaneously fed to a local comparison circuit and a channel interface unit. The interface unit transmits the locally generated signal to the other terminal(s) over one channel while receiving a signal from the other terminal(s) on another channel(s).

For the comparison process, two quantities are generated from the local (VLD) and remote (VR1F and VR2F) voltages. One is called the operating quantity (VOP) and is derived by the vector addition of the local and remote voltages. This addition is performed by a summing and inverting amplifier located on the RELAY module ("L + R"). The output is rectified and filtered to produce a dc voltage for comparison. The other, the restraint quantity (VRES) is obtained by adding the local (VLD), each remote quantity, VR1F and VR2F, on a magnitude basis, after conversion to dc, in a summing and inverting circuit also located on the RELAY module. This output (-VRES) is opposite in polarity to the "operate" voltage (VOP). Further details of the comparison circuit are covered later under "Comparison Technique".

The "operate" and "restraint" voltages are combined and the resultant fed to a level detector which produces a trip signal if the resultant is above the pickup setting. Variable system pickup settings are entered by a knob on the front of the RELAY module and may vary from 2 to 20 amperes (5 A CT) or one fifth of that for 1A CT's. The trip signal lights an indicator labeled "LCB TRIP" on the RELAY module and causes trip relays to operate if tripping has not been blocked by monitoring circuits.

In summary, the local and remote currents are converted to representative voltages at each terminal. By means of a communication channel the remote signals are brought into each local terminal, compared as to magnitude and phase relations, and a trip signal generated accordingly.

The above description has been greatly simplified to cover just the basic system operation. Before covering added functions and logic provided in the system, some discussion of the modulation technique used for remote data transmission is in order. In order to provide accurate and rapid trip determination, the voltage developed by the sequence network at each terminal is reproduced at the remote terminal(s) with a minimum of delay and distortion. The encoding technique is suitable for both audio-tone and fiber-optic data channels. The technique employed in the LCB is known as pulse-period modulation (PPM), where the carrier period is varied linearly with the modulating signal amplitude. In essence, samples of the line current are taken at a 3.4 kHz rate and reproduced as a stepped signal at the receiving end. The envelope of this output is an accurate representation of the original voltage.

The device which develops the pulse train is called the modulator and the unit which translates the pulses to a magnitude wave is called the demodulator. The demodulator uses a sample and hold technique which minimizes the inherent delay in filter circuitry required by other techniques.

One modulator is required at each terminal to produce a local signal for transmission to the remote terminal(s). This unit is part of the modulator-demodulator (MD) module. A demodulator for the signal from one remote terminal is located on the same module. For three-terminal applications a second demodulator is required to convert the signal from the second remote terminal. This demodulator is located on the demodulator/time delay module (DTD).

Further details of the "Modulation Technique" are covered later.

FUNCTIONAL OPERATION

The current transformation package is located behind the relay nameplate and consists of three current-to-voltage transformers (current to current with loading resistors). These low-burden transformers are accurate to 100 p.u. symmetrical (1 p.u. equals one or five amperes). The voltage outputs go to the sequence network previously discussed. While it is desirable that the line current transformers have the same ratio, if there are different ratios, the current settings of the relays (T SET, RELAY module) may be adjusted to provide the same primary current sensitivity at each terminal. The setting range is 2 to 20 amperes for the 5A unit which generally can accommodate a three-to-one ratio difference between line transformers. Careful consideration must be given to the current transformer with the lower ratio, since it may saturate before the current transformer with the higher ratio. The very low-burden of the relay aids in solving this problem.

Correct and reliable operation of a differential relay requires that the quantities being compared be faithful equivalents of the measured primary quantities. This is especially critical during transient conditions, since unequal response in terms of magnitude, phase or time delay will result in a false comparison. In the LCB relay, the local signal prior to comparison is conditioned by a series of circuits nearly identical to the ones needed to process the remote signal. Since the remote terminal may be far enough away to produce a significant real time delay in the received signal with respect to the local signal, to make a valid comparison the local signal must be delayed so that it reaches the comparison circuit at the same time the equivalent real time signal arrives from the remote terminals.

The local delay in the LCB is provided by an adjustable, distortion free delay equalization circuit. This circuit consists of sectionalized all-pass delay networks which supply adjustable delay times up to 8 ms and is similar to a lumped-parameter delay line circuit. It exhibits a linear phase (constant time delay) characteristic over a wide frequency range. A similar design is also used for equalizing the remote signals of a three terminal line application. The system delay circuitry for the local signal is on the RELAY module. The third terminal delay is on the demodulator/time delay module (DTD).

In the LCB relay all the signals required to transmit information from one terminal to another are generated as an integral part of the relay system. The module which connects the LCB System to the communication channel is the interface module. One module is required for each remote channel. Both are identical, except for the label, for a given type of channel. There are two versions of the interface module, one for a fiber-optic channel (IFO) and one for a tone channel IFDT.

The LCB Block Diagrams, Figs. 4 and 5, show the audio-tone interface module, IFDT (see left hand side). This module may be divided into three basic functional elements consisting of carrier receiver, channel monitoring, including receiver for reference frequency, and transmitter.

Terminals 9 and 7 are the inputs to the IFDT receiver. The incoming signals go through an isolation transformer, then through a common-mode noise-rejection circuit to a scaling circuit. Depending on the received composite signal level, this circuit may be set by a link to act as either an amplifier or attenuator. The carrier signal is then adjusted to the nominal AGC level using a control accessible at the front panel of the module (RX ADJ). At the output of the scaling circuit, the signal is sent to both the carrier receiver circuit and to the frequency detector circuit. Continuing with the carrier receiver path the reference signal is first removed using a notch filter, followed by a band-pass filter which eliminates noise and spurious signals outside the desired 1 to 2.5 KHz modulated carrier range. The automatic gain control (AGC) unit maintains a nearly constant magnitude signal going to the demodulator.

The AGC control voltage is used for High and Low signal level monitoring as well as the reference for signal-to-noise (SNR) monitoring.

In the high/low limit monitoring circuit, the AGC control voltage is compared with predetermined levels. The differential comparison function of the relay is permitted only when the incoming carrier is within these set limits (± 10dB).

In the SNR monitoring circuit, the carrier signal output from the AGC circuit is conditioned by a band-reject circuit (carrier removal), and only the noise voltage will remain at the output of this circuit. An absolute-value circuit is used to further process the noise into a dc quantity which in turn is to be compared with a voltage derived from the AGC control voltage for the desired SNR level. If the noise voltage equals or exceeds the set level, a block signal will occur. The use of the AGC control voltage for the SNR level setting permits the SNR monitoring to be a truly relative function not tied to any specific input signal or noise level. The noise voltage obtained in this circuit is used yet for another purpose.

In the relay design, as described earlier, the remote and the local current quantities are evaluated by circuits which perform the vector comparison and magnitude comparison. The outputs of the two comparisons are then combined to determine a trip. If the recovered remote current contains noise due to a noisy channel, it is desirable that this noise can be recognized and eliminated. The very nature of the comparison technique and the characteristics of random noise have already provided some inherent noise rejection. However, additional noise rejection is achieved by relating the noise voltage (VN) to the trip reference. This feature provides an adaptive desensitized trip maintaining the comparison accuracy in the presence of channel noise.

The frequency detector circuitry monitors a reference frequency that is received with the carrier signal. The signal from receiver scaling circuit goes through a band-pass filter that eliminates noise and spurious signals outside the desired 2700 to 2850 Hertz reference range including the unmodulated carrier signal. The limiter converts the analog signal to a digital signal and provides on board indication if reference level falls below the setting of 2762 Hertz level detector. The frequency discriminator and detector circuitry performs a comparison of the received reference frequency to a reference frequency and provides an output if within predetermined frequency limits.

The high/low carrier frequency detector is a fast responding detection circuit which directly senses the carrier signal and provides an output if the signal is outside of its range for more than one cycle.

The output of the SNR circuit is passed thru an "OR" gate with the output of the Reference Frequency detector circuit producing a SNR indication if abnormal noise or a frequency translation condition occurs. This composite signal is stretched to provide an additional 100 ms delay before returning to normal.

The output of the Lo and Hi level detectors each provide an indication on the front of the relay when an out-of-limits signal is received. After the indication, the Lo and Hi level detectors are passed through an "OR" gate, and the output of the "OR" gate is pulse stretched by 600 ms to be sure the system has returned to normal before unclamping the LCB-II. The outputs of the Reference Frequency Detector, the SNR detector, and the Hi/Lo Level detector are combined using an "OR" gate to provide a "HIGH" on the EN signal and a "LOW" on the CA signal when any of these channel abnormalities occur. The two separate restore timers discussed above provide the appropriate time delays for system restoration.

The transmitter combines the carrier signal with a crystal generated reference signal to obtain a composite. The transmitter-level control is a combination unit which is used to adjust the transmitter output to the level required by the tone channel used with the relay system. The signal conditioning circuit converts the incoming square waves to a composite sine wave, and the protection and isolation unit provides a safe and matched connection to the channel.

The LCB Block Diagram Figs. 6 and 7 shows the optical interface, IFO (see left hand side) which connects the relay system directly to the fiber channel. The transmitter is an amplifier diode combination which turns a fiber-optic emitter on and off to generate light pulses with the off/on period determined by the pulse-period modulation output. The receiver consists of a photo-diode producing electric pulses which are then amplified through a trans-impedance amplifier, passed through a band-pass filter and into an automatic-gain control circuit thereby providing a relatively constant-amplitude carrier signal for the demodulator.

The channel-condition monitoring section comprises two detection circuits. The low carrier signal detection uses the AGC control voltage to detect carrier signals that are below a preset level. A low carrier signal signifies a malfunction in the channel. Since the AGC voltage is a relatively slow responding signal, this detection is implemented primarily to provide an early warning indication that problems are developing in the channel. An adequate margin has been given in the design to accommodate the time delay effect in the AGC voltage. The carrier-frequency monitor, on the other hand, is a fast-responding detection circuit. By sensing the carrier signal directly, any fast interruption or change in the channel lasting for more than one carrier cycle will activate this circuit instantly. The two detection outputs are combined to produce a channel-malfunction signal.

The channel trouble outputs (EN) on the channel-interface modules are applied to logic on the RELAY module to immediately discard the remote signal and block tripping. The LCB under this condition can still be used as an overcurrent function after 45 ms by using the local sequence quantity only, if desired, (link selectable), on the AXLM module.

Time-delayed indication and alarm is provided for sustained loss-of-channel by means of a 500 to 5000-ms timer, CA indicator and alarm on the AXLM module.

Final breaker-tripping control is accomplished by means of type-AR relays mounted on the LCB trip module (ARTM-1 for LCB trip, AR-1), (ARTM-2 for DTT trip, AR-2). Each AR is provided with four (4) normally open contacts, two (2) for tripping and two (2) for spares. Those contacts for tripping have a series reed relay, which when energized with dc currents in excess of 0.5 amperes operate to cause an LED trip indication.

The AR tripping circuits and relay indication are blocked from false operation for a period of approximately 3.5 seconds during dc power up conditions in order to permit associated relay and communication circuits to become stable. This power-control circuit also blocks the system immediately during momentary loss or dip of +15 Vdc. PSME from the ALS power supply actuates this circuit as well as blocking the modulator output during power up/down.

Other features incorporated in the LCB system are selection of overcurrent trip on a loss-of-channel, remote control of overcurrent trip, ability to reset indicators remotely, and desensitized trip on line energizing. These are all included as part of the AXLM module, with additional selection on the MD for the OCCC features.

Six options are selectable in the LCB during a loss-of-channel condition, and are controlled by link "LC", which in turn through signal BS control the LCB trip output. "OT" allows trip while "BLK" blocks overcurrent trip on a loss-of-channel. "OTD" allows overcurrent trip only after loss-of-channel has been present for a time delay of 0.1 to 2.0 seconds, adjustable by the user. Unblock tripping, "UB", is commonly used where the channel medium is power-line carrier, where momentary loss-of-channel could occur during some internal faults. This feature allows overcurrent tripping for 150 ms following loss-of-channel, after which time, trip is blocked. If "UB/OTD" is selected, then unblock tripping is allowed, followed by the time-delayed overcurrent trip. Another feature associated with unblock tripping is unblock trip on reclose. If selected, "UR-IN", then unblock trip on reclose will be permitted again for up to 150 ms assuming the initial LCB trip had occurred in the preceding 2.5 seconds. Unblock trip on reclose requires 52b-breaker status information which is optional via an optically-isolated voltage-selectable input buffer.