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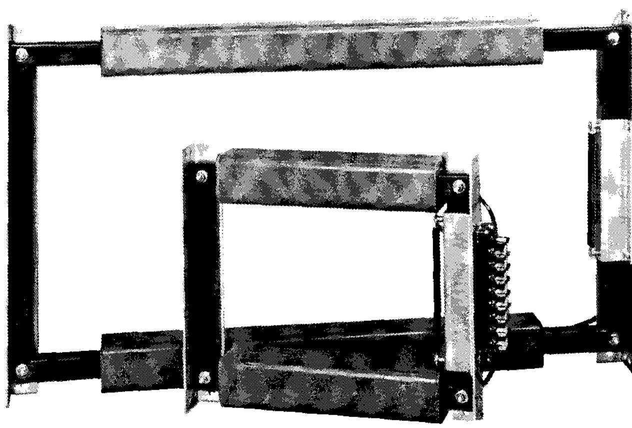
Solid state construction and high grade components applied conservatively help produce reliability. Redundancy is built into the system to provide back-up modes of operation in case a component fails. A fail safe concept prevails in the design. Simple test provisions permit easy periodic assurance that the system is operational. The solid state relay is operated solely by the ground current sensor without depending on a supplemental control power source, transformer and wiring. Energy from the ground fault trips a molded case circuit breaker directly without need for a control power source and connections. If applied correctly, the user can be confident the system will perform properly.



GROUND FAULT CURRENT SENSORS
LARGE GT-1530 AND SMALL GT-912

GROUND FAULT CURRENT SENSOR

The ground fault current sensor is very similar in appearance and function to a window type instrument current transformer. It is different, however, in that it is generally larger and incorporates special means for testing the ground fault protection system. Basically, the current sensor is a rectangular iron core on which are placed two parallel main windings. The combination of core and windings responds to the magnetic field of the current in the conductors passing within the window and produces a generally proportional output signal.

GROUND FAULT CURRENT SENSOR Cont'd.

Ground current is usually sensed in either of two ways. One is by locating the sensor around the one or more conductors in the ground path which carry all the ground path current. Used in this way the sensor acts exactly like a current transformer. It is important that only conductors in the ground path pass through the window - all other phase and neutral conductors must be excluded.

The second and more common way to sense ground current is to run all of, the phase and neutral conductors through the window of a single ground sensor - any ground path must be excluded. When used in this manner, the sensor determines the ground current by subtraction - actually the resultant of vector addition. In a normal circuit without a ground fault, all of the current flowing to the load in the phase and neutral conductors is also returning to the source on these same conductors. The magnetic flux caused by currents flowing in one direction is neutralized by equal magnetic flux caused by equal currents flowing in the opposite direction. If a fault occurs from phase to ground on the load side of the current sensor, some current will flow in a ground path and return to the source through a path outside the current sensor window. More current is therefore passing through the sensor in one direction than is returning through the sensor - the difference being the ground current. The resultant magnetic field causes the sensor to produce an output signal generally proportional to the current flowing in the ground paths.

In most applications it is more practical to locate the current sensor so that it encircles all phase and neutral conductors either on the line or load side of the current interrupting device. Therefore the sensor must have a large opening through which all the cables or bussing may pass. Various sizes of current sensors are provided having windows ranging from approximately 9" x 12" to 15" x 30". Since the sensor is large and encircles all of the phase and neutral conductors, it is important that the conductors not be located too close to the core. If they are, local saturation effects may occur in the core, reducing the accuracy of the sensor and affecting operating characteristics of the ground fault protection system. The parallel windings of the sensor help avoid the adverse effects of local saturation but for reliable accuracy the conductors should be located at least two inches from the core. This two inch dimension also accommodates the sensor windings and provides generous electrical clearances between circuit conductors and current sensor. With this in mind, it is obvious that the window opening, which may at first appear overly large, is actually not excessive.

Product Data

GROUND FAULT CURRENT SENSOR Cont'd.

For applications where the sensor encircles only a ground path conductor, the sensor size may be considerably smaller since not only are fewer conductors involved (not all phase and neutral conductors with accompanying insulation or clearances) but also the two inch magnetic clearance is not necessary. In fact, a standard 3000A. current transformer (having a 600:1 ratio) can be used with good results, but does not offer the testing provisions built into the Square D current sensor.

Two main windings are provided on the sensor. They are located on opposite sides of the core, physically protected by a red glass polyester cover, and connected in parallel. This arrangement not only reduces the possible problems from local saturation of the core, but also provides greater reliability. Even the unlikely occurrence of an open or shorted winding is anticipated and redundancy provided. If an open should develop in one winding, the remaining parallel winding will operate the ground fault system satisfactorily. If a few winding turns become shorted, that winding will either continue to function, perhaps with somewhat reduced sensitivity, or will probably soon melt open and permit the remaining winding to function alone. A short of the entire winding, very unlikely except perhaps due to not removing the shorting jumpers after installation, actually shorts both windings and the failure to operate would be apparent during the test operation.

A special test winding is included on the current sensor to permit testing the entire ground fault protection system. This winding is superimposed on one of the main windings. A resistor, mounted on the sensor, is in series with the test winding and applying 120 volt power produces the same output from the main windings as a 2500 ampere ground fault causing the ground fault system to function as it would under ground fault conditions. More details of this testing function are discussed later.

A terminal board is mounted on the sensor to enable convenient connection of the sensor windings to the relay and test circuits. Since open circuited sensor windings can produce high voltage if current flows in conductors passing through the window, a prominent label near the terminal board cautions: To prevent high voltage output jumper across terminals X1 X3 to X2 X4 before installing or servicing. Remove jumper when all wiring is complete.

The core consists of laminations of magnetic steel securely bolted at the corners. If necessary, one leg of the core may be removed to place the sensor around existing circuit conductors and the core leg replaced. Care is required in reassembling the mortised joints to restore the magnetic characteristics of the core.

GROUND FAULT RELAY

The ground fault relay receives and evaluates the signal from the current sensor and, when necessary initiates opening of the circuit interrupting devices in accordance with the relay's time characteristic. With emphasis on reliability, the solid state relay is composed of high grade transistors, triacs, diodes, capacitors, resistors and other components incorporated in deliberately redundant circuitry to provide alternate, back-up operation in the remote event some component malfunctions.

This ground fault protection system is primarily intended for service entrance and larger feeder applications. System coordination is important. If practical, only faulted portions of the system should be disconnected and circuit interrupting devices near the source should remain closed to keep unfaulted circuits in operation. Both current pickup and time delay are used to help provide this coordination.

The relay is designed so it may respond to ground currents 200 amperes and larger detected by the current sensor. A calibrated dial on the front of the relay permits continuous current pickup adjustment from 200 to 1200 amperes. Two hundred amperes is considered a practical minimum value - sufficient to accomplish reliable operation of the ground fault protection system including direct tripping of a molded case circuit breaker. Destructive ground faults occurring in the zone protected by these devices almost always far exceed 200 amperes and therefore could activate the relay. Ground currents less than 200 amperes either result from harmless charging currents or minor faults which are usually not considered dangerous enough to justify de-energizing the circuits. Often a relay pickup setting of even 200 amperes is considered too sensitive and the relay is deliberately set higher. The 1971 National Electric Code indicates in paragraph 230-95 that this pickup setting cannot exceed 1200 amperes for service entrance applications. This NEC designation of 1200 amperes has been used as the upper limit of the adjustment range. The 200 ampere to 1200 ampere pick-up adjustment of the relay therefore permits the relay to deliberately ignore ground currents up to a maximum setting of 1200A. in the expectation that a fault will clear itself or be interrupted by other downstream protection.

For good coordination ground fault protection applied on service entrance and large feeders should contain some time delay to permit the fault to clear itself or permit downstream devices to operate to clear the fault. Therefore, each relay is provided with a specific time delay characteristic which may be either a nominal 0.1, 0.2, 0.3 or 0.5 second as shown on the accompanying curves. The time delay characteristic is factory set and not adjustable. (Since time delay characteristics are selected as the system is designed and equipment chosen there is seldom a need to change these time characteristics after installation.) A relay time delay of approximately 0.1 second will allow several cycles for a fault, especially an

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GROUND FAULT RELAY Cont'd.

arc, to possibly extinguish itself or will permit regular circuit breakers or fuses downstream to open if the current is large enough to cause their instantaneous operation. A relay with a time delay characteristic of 0.2 seconds will wait while a lower echelon 0.1 second delay ground fault relay operates first. Similarly a 0.3 second relay will permit a 0.2 second relay to function first, etc. The GP relay design produces time current curves which are sufficiently separated so that, even allowing for tolerances and the time for circuit interrupting devices to function, there will be reliable selective coordination between successive time relays. A nominal 0.4 second time delay would not assure this and has therefore been omitted. The nominal 0.5 second maximum time delay permits as much system coordination as is normally practical and thus longer time delays are not offered. In this way, using relays with progressive time delays at various echelons in the system will provide selective coordination and unfaulted circuits will not be needlessly shut down.

The time characteristic is the result of reliable timing circuit design. For the most part, each time current characteristic is generally horizontal at approximately its nominal time value. At lower current values, the curve has an inverse slope which indicates somewhat longer time delay. Lower current faults produce less damage and can be tolerated longer. The time characteristics therefore permit more time for the fault to try to clear itself before the ground fault protection system opens the circuit interrupting device. They also allows slightly more time for a persisting low current fault to produce enough obvious effects to assist in locating the point of trouble during inspection and repair.

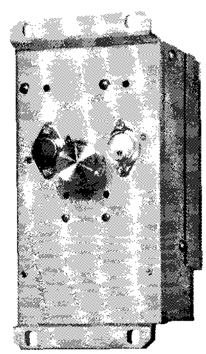
The power to operate the relay is obtained only from the current sensor. Consequently the relay is isolated from the main circuit and not affected by lightning and other transients on the main circuit which might cause false operation of the relay. The relay can withstand ground fault currents up to 100,000 amperes RMS symmetrical and has a built-in self-protecting instantaneous operation at currents of 32,000 amperes and above. Operating time then becomes approximately .025 seconds (1-1/2 cycles) regardless of the normal time delay characteristic. Since currents of this magnitude will cause most circuit protective devices to function instantaneously, this feature of the relay should not cause coordination problems. In fact, it offers additional assurance of fast interruption of large ground faults.

GROUND FAULT RELAY Cont'd.

A small 2.5A standard FNM fuse is provided to further increase reliability. This fuse will open only in the unlikely event that some critical component in the solid state relay circuit fails, any back-up means also fails and the ground fault current continues much longer than the normal time delay of the relay. If the relay has not functioned the fuse will blow at a rate corresponding to approximately one second at a ground current of 25,000 amperes, 10 seconds at 5,000 amperes, and one minute at 2,500 amperes. When the fuse blows the circuit breaker ground trip coil is immediately energized, causing instantaneous interruption of the faulted circuit.

The relay is normally mounted vertically within the equipment enclosure, behind a door or panel, and is thus accessible only to authorized personnel. As an alternate, the relay can be provided so that the nameplate and current pickup adjustment dial are located on the front of the equipment so as to be easily seen and the dial easily adjusted. In this arrangement, the relay is mounted on the inside of the front door, and the adjustment dial projects from the rear of the relay into a hole in the front door as shown below.

ALTERNATE RELAY MOUNTING WITH NAMEPLATE AND CURRENT ADJUSTMENT ON FRONT OF EQUIPMENT ENCLOSURE



MODIFIED RELAY WITH ADJUSTMENT DIAL PROJECTING FROM BACK

A terminal board located at the lower end of the ground fault relay accommodates the 2.5A back-up fuse and enables connection to the current sensor and to the tripping circuit. Wires from the relay to the sensor should be no longer than 25 feet and not smaller than No. 14 copper wire. Wires from the relay to the ground trip coil should be not less than No. 14 and not exceed 50 feet in length.

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CIRCUIT INTERRUPTING DEVICES

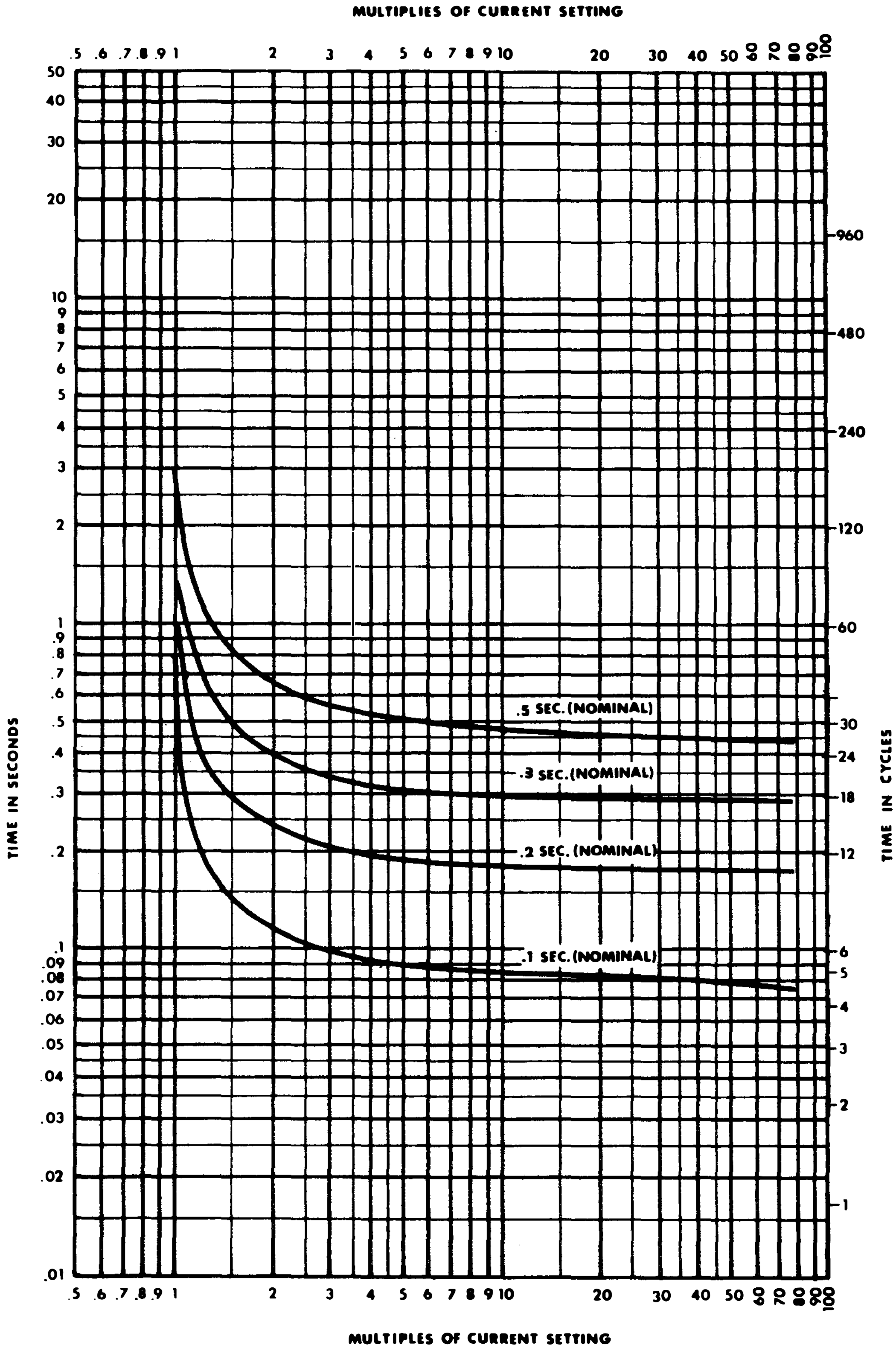
The ground fault protection system does not interrupt faults but rather causes a circuit interrupting device to open the circuit. Obviously the circuit interrupting device must have sufficient capacity to interrupt the fault. The ground fault sensor may be located on the line side or the load side of the circuit interrupting device and it is well to note that ground faults on the line side of the sensor will not be detected and faults on the line side of the interrupting device will not be cleared.

The ground fault relay operates to energize a tripping coil of the circuit interrupting device. If the circuit interrupting device is a Square D molded case circuit breaker up to PC 2500A. size, sufficient energy will be transmitted from the ground fault current via the sensor and the relay to instantaneously activate a ground trip mechanism in the circuit breaker. The special ground trip coil is similar to a standard shunt trip coil but operates at approximately 24 volts ac, and uses no series coil clearing contact switch since it is not necessary and might produce damaging high voltage by opening the secondary of the current sensor while the magnetic field is still present.

Some circuit interrupting devices such as low voltage power circuit breakers and BOLT-LOC bolted pressure switches require more tripping power than might be supplied directly by the ground fault current. In such applications the ground fault relay may be used to activate an auxiliary 24 volt "ice cube" or similar relay (maximum inrush 7 VA) and this relay may then connect a conventional shunt trip coil to a reliable control power source.

CIRCUIT OPERATION OF THE GROUND FAULT PROTECTION SYSTEM

Consider all phase and neutral (if used) conductors passing through the sensor. When circuit conditions are normal, the currents in all these conductors add up to zero and the sensor current transformer produces no signal. When any ground fault occurs, however, the currents add up to equal the ground fault current and the sensor produces a signal proportional to the ground fault current. The same signal is also produced with the



TIME-CURRENT CURVES

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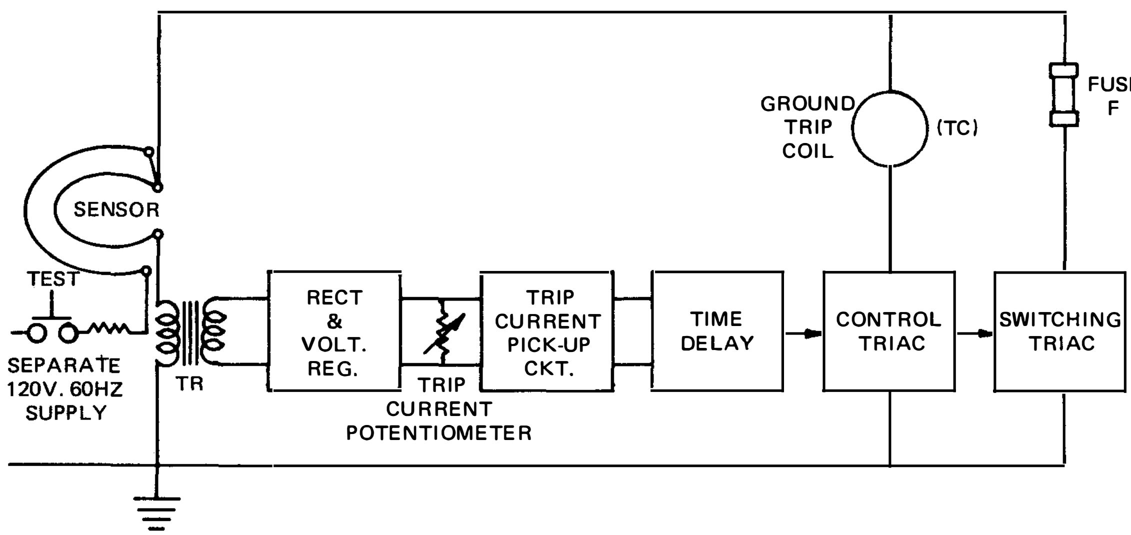
CIRCUIT OPERATION OF THE GROUND FAULT PROTECTION SYSTEM Cont'd

alternate arrangement of only the ground path conductor passing through the sensor window. This signal provides power to the ground fault relay which trips the circuit breaker. A block diagram of the circuit appears below:



CIRCUIT BLOCK DIAGRAM

When ground fault current exceeds about 100 amperes, the switching triac conducts and shunts most of the sensor output through transformer TR. The control triac will not conduct until the end of the time delay period.

The output of TR is rectified and limited to 30 volts. When the product of the ground fault current, times the sensor ratio of 1:600, times the TR ratio of 1:48, times the resistance of the trip current potentiometer circuit reaches 26 volts, the trip current pickup circuit will turn on. The trip current potentiometer is adjusted as the relay dial is rotated through calibration marks 200 to 1200 amperes.

When the current trip pickup circuit turns on, the time delay period begins. At the end of the timing period, the control triac turns on. Because the rectified output of TR is limited to 30 volts, the time delay is practically constant for all currents over 3 times the trip current setting as indicated in the curves.

CIRCUIT OPERATION OF THE GROUND FAULT PROTECTION SYSTEM Cont'd.

When the control triac conducts, it shorts out the gate control circuit to turn off the switching triac. The sensor output then flows through the control triac and picks up ground trip coil TC. Ground trip coil TC trips the circuit breaker to interrupt the ground fault.

For very high fault currents, the switching triac will conduct continuously to limit the output voltage of the sensor. A 3 ohm resistor in this triac load circuit develops enough voltage drop to pick up the trip coil (24 volts). A ground fault lasting for less than the time delay period will not pick up the ground trip coil, thus eliminating nuisance tripping of self-clearing faults.

Ultimate protection against component failure is provided by the fuse F. This 2.5 ampere type FNM fuse will not blow unless some component of the solid state circuitry has failed and the ground fault current continues to flow well beyond the normal time delay of the GFR. When the fuse blows, the shunt trip coil will be energized immediately.

TESTING THE GROUND FAULT PROTECTION SYSTEM

A simple means for testing has been included to simulate as much as possible operation under actual fault conditions yet not cause harm to the equipment. Any 120V. ac, 60 Hertz source capable of 3 amperes properly connected to the test terminals energizes the test winding which in conjunction with the regular sensor windings produces the same sensor output as a ground fault of approximately 2500 amperes. The 2500 amperes value is specifically selected since ground faults usually exceed this value and this value insures sufficient sensor output to activate the relay regardless of where its trip current pickup setting might be. For example, consider the most difficult situation where the trip relay current may be set at the maximum 1200 amperes. This could then be permitting a ground current of slightly less than 1200 amperes to flow. If by chance, due to being out of phase, the ground current produced a magnetic field in the sensor which was in opposition to that caused by the test current, the resulting output of the sensor would be reduced and perhaps not operate the relay implying malfunction of the ground fault system. A test output from the sensor corresponding to a 2500 ampere ground fault will be sufficient to override the neutralizing effect of the nearly 1200A. ground fault current and still exceed the 1200A. pickup setting on the relay to cause test tripping of the breaker and a practical test of the system. If desired, a more precise testing calibration check of the relay can be done by removing the relay and testing it in accordance with a prescribed procedure.

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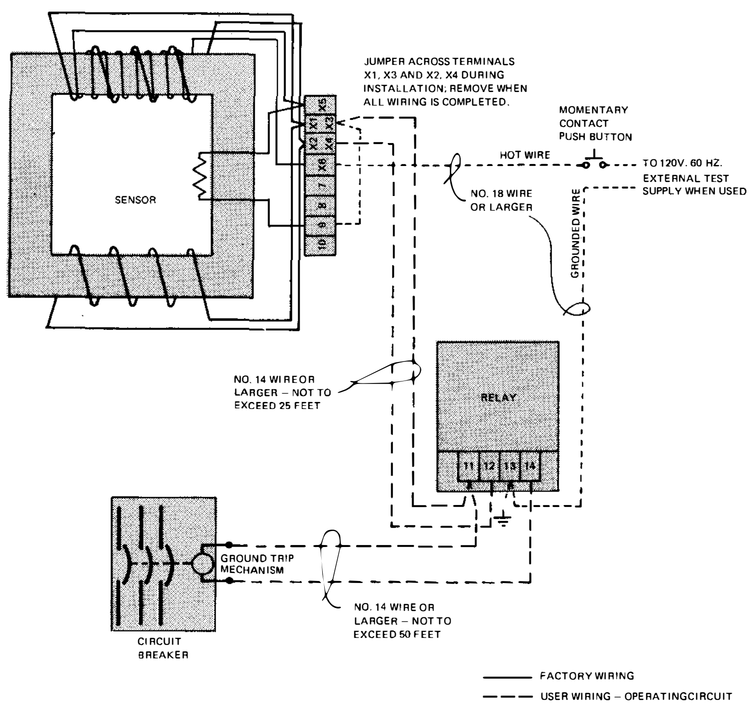
TESTING THE GROUND FAULT PROTECTION SYSTEM Cont'd.

The test winding is permanently mounted on the sensor core. The winding having many turns might be expected to develop dangerous high voltage during large ground faults but this has been anticipated and avoided. The test winding is connected to and works in conjunction with the regular windings and the ground fault relay so that under normal or fault conditions the voltage at the test circuit terminals or the test supply circuit will never be excessive.

In accordance with good maintenance practice the ground fault protection system should be tested when installed, at least once a year and immediately after each time the circuit interrupting device opens due to a fault of any kind.



WIRING DIAGRAM

LEXINGTON HEADQUARTERS SALES DEPARTMENT

ROOhlson/pb