Ground Fault Protection

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Abstract - **This paper describes a simple method of including Ground Fault Protection within the physical constraints of an existing aircraft relay design.**

I. GROUND FAULT PROTECTION

A Ground Fault Detection and Protection method is typically used to continuously monitor an AC electrical circuit for fault conditions, instantly disconnecting the power in order to minimize loss of life or equipment damage. This is particularly pertinent in 115V, 400Hz, three phase aircraft power distribution to motors used in equipment cooling, hydraulic power and fuel systems.

II. CLASSIC THEORY

For three phase AC powered loads, three separate power lines provide power to the load. The voltage waveforms on these three lines differ only in their timing, or phase relationship. A fourth wire may provide a neutral connection to the load. In the case of balanced loads, where the current in each of the three phases is equal, the current in the neutral wire will be zero. The neutral wire may therefore be eliminated, as it is not necessary for the purpose of carrying current. The vector sum of the currents drawn from the three phase lines will be zero with a balanced load as in [1]. A non-zero sum of the current indicates an unbalanced load and that a current is returning to the generator, or current source, via an unintended path. This is the ground fault current.

The ground fault current for a three-phase system, without neutral, may be measured by performing a vector summation of the phase currents. This summation may be performed by a current sensing transformer with the phase currents passing through the common aperture in parallel. The magnetic field induced in the transformer core is then the vector sum of the three individual phase currents and the voltage induced in the secondary winding placed on the transformer provides a signal representing the vector sum of the currents, the ground fault current.

III. REQUIREMENTS AND DESCRIPTION

A. Electrical Requirements

A fault-protected relay includes fast contact opening to reduce the fault duration and accurate sensing in a fault current environment.

The ability to function is required under adverse environmental conditions and in an electromagnetic environment that may include power line interference, High Intensity Radiated Fields and induced surges due to lightning strike. The basic requirements are shown in the system block diagram (figure 1) below.

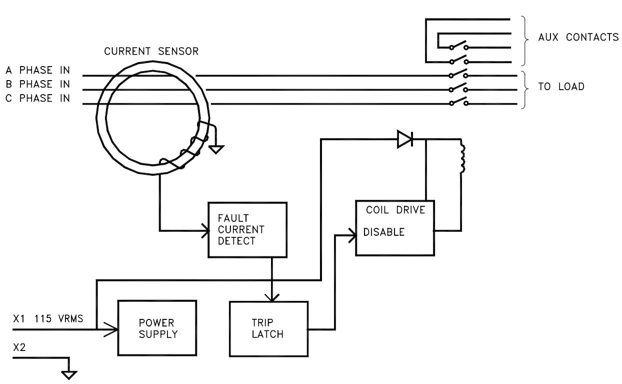


Figure 1. System Block Diagram

B. Physical Requirements

The physical requirements include form, fit and function commonality to enable direct replacement of the existing aircraft relay design.

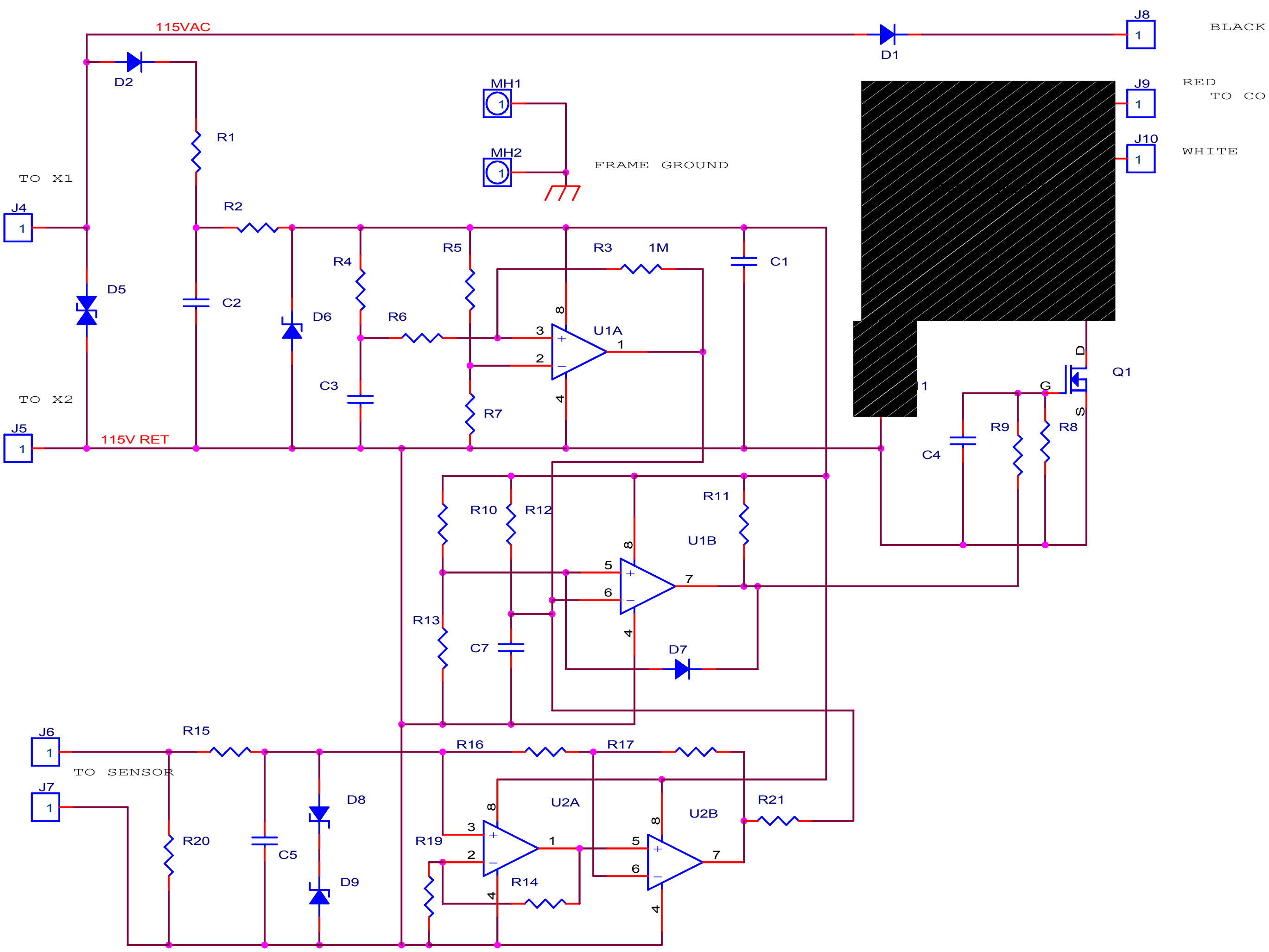
The available space envelope for some applications may be increased, but the mounting footprint must be the same as the non-protected device in order to provide direct replacement. There is also a weight increase of 10% due to the added components and increase in height.

C. Circuit Description

Figure 2, below, is a schematic diagram of the model HDG Ground Fault Protected Relay control module.

This has been designed to provide a direct replacement for a relay having an AC coil but not having the ground fault detection capability. The circuit was designed such that no modification of the wiring external to the relay is required in order to add the ground fault detection capability. Minor modification of the circuit provides compatibility with the DC coil version of the relay. The major functions of the circuit of figure 2 are:

1) Rectification of applied voltage to provide coil power.



2) AC to DC conversion to power the control electronics.

3) Circuit initialization at power application.

4) Coil drive to close contacts at power application.

5) Fault current sensing and detection.

6) Coil disconnection when fault detected.

7) Latching the fault detected condition until power removed.

Diode D1 provides half wave rectification of the applied AC power for the coil. Diode D2, resistors R1 and R2, capacitor C2 and zener diode D6 provide the power source for the control circuit.

Comparator U1A provides the initialization at power application to force the circuit to drive the coil, thus closing the contacts. The initialization lasts for approximately 10 milliseconds until capacitor C3 charges to one half the voltage established by zener diode D6. During this initialization period the coil driver FET, Q1 is forced on and the sense current ignored.

Circuit Diagram

Comparator U1B continuously monitors the signal from the current sensor. As long as the signal at pin 6 is less than the signal at pin 5, the comparator output pin 7 stays high, going low when a fault occurs and turning off the coil-drive FET. The low level at pin 7, acting through diode D7, lowers the reference voltage at pin 5 which latches the comparator output and prevents the relay coil from being re-energized when the fault current is removed.

The secondary winding of the transformer is connected to the circuit at pins J6 and J7. Resistor R20 provides a load on the current sense transformer preventing it from saturating due to the magnetic fields produced by the fault current. It also provides scaling of the signal. R15 and C5 provide filtering to prevent high frequency noise spikes from being detected as a fault current.

Diodes D8 and D9 function as signal limiters to prevent circuit damage due to high amplitude transients.

Amplifiers U2A and U2B function as a full wave rectifier of the fault current signal. C7 provides additional filtering of the rectified current fault signal.

During normal operation (in the absence of a ground fault) a network of diodes and zener diodes (within the hatched area) provides back EMF suppression and connects the coil drive power through FET Q1.

When a fault current is sensed the FET Q1 is turned off and the release speed up circuitry [within the hatched area] functions.

This release circuit achieves a release (disconnect) time of 10 milliseconds. The latched condition is reset by removing power for longer than the control module power holdup time.

D. Physical Implementation

A minimal increase in overall volume required that the measurement transformer and control module be fully integrated into the internal relay connection assembly.

The measurement transformer integration was accomplished by core material selection, core construction and insulation techniques to keep within the overall 6.6cm (2.6inches) can diameter of a 50A relay.

A single multilayer PCB is used to hold all protection circuit components other than the current transformer.

The only external physical difference is an increase of 1cm (0.4 inches) in height, which is shown in figure 3.

Figure 3. Height difference.

III. PERFORMANCE

The desired measurement accuracy of 1.5A+/-0.5A, 400Hz and 10ms contact opening time was achieved with minimal increase [14%] in relay height.

IV. APPLICATIONS

In addition to new applications, the HDG relay may be directly substituted for the correspondingly configured H series relay in an existing application. Existing wiring may be used minimizing upgrade time and cost while maintaining the reliability inherent in the H Series relay.

ACKNOWLEDGMENTS

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REFERENCES

[1] Standard Handbook for Electrical Engineers, Fink and Beaty, 11th.edition, McGraw Hill, Inc. **2-47**.