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RESEARCH ARTICLE OPEN ACCESS

Design and Implementation of a Single Phase Earth Fault Relay

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Abstract:

This research paper is about the design and implementation of single phase earth fault relay with alarm system**.** Protection coordination is the main part of all electrical power systems. To ensure a high quality and reliable operation of the power systems, an electrical power fault must be cleared within the shortest time. This can be done by proper coordination between the protection relays. The design was done using embedded system technology. This is to reduce component count, keep the system simple and cost effective.

Keywords **— Earth, microcontroller, current sensor, Alarm unit, relay.**

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I. INTRODUCTION

An earth fault is a situation whereby there is a contact between an energized conductor and ground or equipment casing. The return path of the fault current is through the grounding system and any personnel or equipment that becomes part of that system, earth faults are frequently the result of insulation breakdown. It's necessary to notice that damp, wet, and dust-covered environments need further diligence in design and maintenance. Since water is conductive it exposes degradation of insulation and increases the potential for hazards to develop. Earth fault relays are designed to detect phase to ground fault on an electrical system then disconnects the electrical system/load from the phase. By quickly detecting the ground fault and initiating the appropriate response, ground fault relays improve electrical safety for workers and minimize damage to equipment due to electrical faults without affecting the uptime of critical operations.

The nominal earth fault relay has a trip time and current limit setting/control, and its detection is between a phase and ground, making the system complex and expensive.

The purpose of this project is to develop a system that senses the earth fault in single-phasing system, disconnects the system/load from the phase line and alerts the user about it, it consists of two electrically isolated current sensors, one connected in-series with the phase line and the other connected in-

series with the neutral line, a microcontroller based control system continuously monitors the quantity of current passing through each phase and neutral lines. In ideal conditions the amount of current passing through the phase and neutral should be same. In case of earth fault, the amount of current entering into the phase line will not be equal to the current leaving through the neutral line. In such situations the microcontroller-based system alerts the user about this in the form of visual indication and audible alerts, then disconnects the electrical system from the phase line.

One Phase System

Single phase electric power refers to the distribution of electric system using a system in which all the voltage of the supply varies in unison. Standard frequencies are either 50 or 60 Hz. A phase load may be powered from a 3 phase distribution lines by connection between a phase and neutral (120V or 220V). On higher voltage system (kilovolt), a single phase transformer is use to supply a low voltage system. Single phase power distribution is used especially in rural area, were the cost of a three phase distribution network is high. Typically, a third conductor is called a ground or earth use for safety, and ordinarily only carries significant current when there is a current fault.

Although the single phase system has safety (earth conductor) but this system cannot perfectly protect the electrical circuit, electrical equipment and also human life from the high voltage. So, the circuit breaker is needed to make more protection.

A. The Scope of Research

The research provides exposure on:

1. Single phase Earth fault and earth fault protection system.
2. Types of Electrical Faults, Electrical systems and Load.
3. Current measurement and current sensors.
4. Embedded C program and Microcontrollers.
5. Analog to digital modules/devices.

B. Objectives of this Research

The specific objectives of the study are:

1. To be able to determine an earth fault in an electrical system.
2. To be able to determine the amount of current flow through a phase and neutral line.
3. To be able to disconnect an electrical system or load from the MAINS on the event of Earth fault.

C. Application of the Study

1. The earth-fault relay is used both as primary and back-up earth-fault protection relay for feeders, transformers, generators and motors.
2. The Earth-Fault relay can be used to protect residential electrical appliance against Earth fault.
3. The earth fault relay can also be used to protect persons from Electrical Shock.

II.ELECTRICAL FAULTS

A fault in electrical are any abnormal situation in an electrical systems in which the electrical current may or may not flow through the supposed parts. Equipment failure can also be attributed to some defect in the circuit such as loose connection, insulation failure or short circuit etc. Major electrical faults are:

A. Over-Current Fault
B. Short-Circuit Fault
C. Lightning Fault

A. Over-Current Fault

The National Electrical Code defines over current as any current in excess of the rated current of equipment or the amp city of a conductor. These systems are designed to keep the flow of current in a circuit at a safe level in order to prevent the circuit conductors from overheating. In term of over-current fault, the fuse or wire may melt or damage the other elements of the circuit when a current greater than that which a circuit or a fuse is designed to carry.

B. Short-circuit fault

A short circuit in an electrical connection that permits a current to flow in different path from the one originally supposed. While an "open circuit", is an opposite of short circuit and has an infinite resistance between two nodes. It is an abnormal low-resistance connection between two nodes of a circuit that are meant to be at different level of voltages. This results in an excessive electric current (over-current) and potentially causes circuit damage, overheating, fire and explosion. Although, sometimes results obtained in faulting circuit show that there are some cases where short circuits are caused intentionally, for example for the purpose of voltage-sensing crowbar circuit protectors. In circuit analysis, the term short circuit is used by analogy to design at a zero-impedance connection between two nodes.

In an ideal short circuit, this implies there's no resistance and voltage drop across the short. In a simple circuit analysis, wires are considered to be shorts. But real circuits, the result is a connection of almost zero impedance, and almost no resistance.

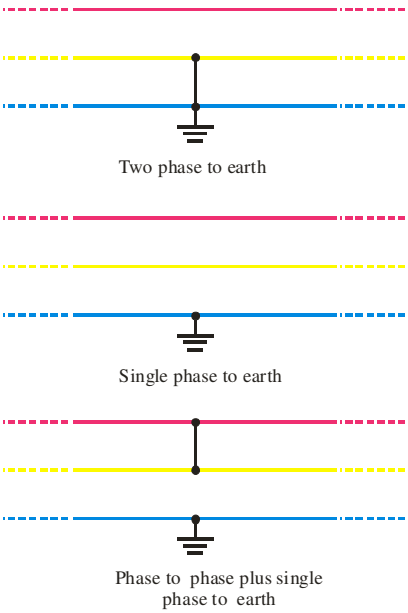

Fig. 1. Short circuit fault associated with single phase

C. Lightning Fault

Lightning is the discharge of static electricity within a cloud that is visible, between clouds, or between the earth and a cloud. Scientists are still unaware what causes lightning, but most experts believe that it is caused due to different kinds of ice interact in a cloud. Updraft in the clouds separate charges, so that positive charges flow towards the top of the cloud and the negative charges flow to the bottom of the cloud. When the negative charges moves towards the bottom, a "stepped leader" is form. The leader rushes toward the earth in 150-foot discrete steps, forming an ionized path in air. The important part of the lightning discharges current is carried in the return stroke, which flows on the ionized path. One of the non-permanent faults is cause by direct lightning phenomena. The example of permanent fault can mostly been noted on electrical equipment.

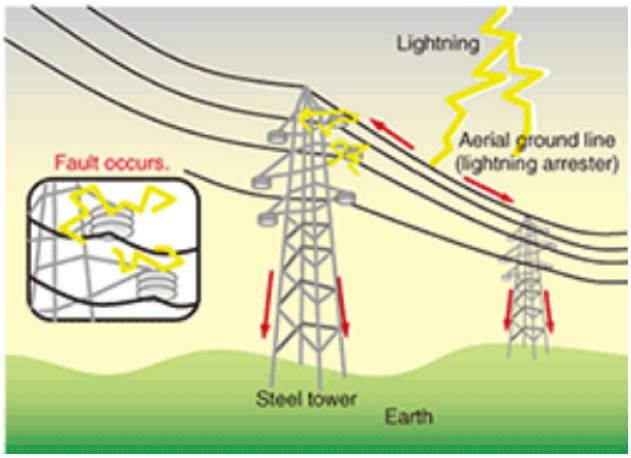

Fig. 2: Power fault cause by lightning

D. Block Presentation Of An Earth Fault Relay

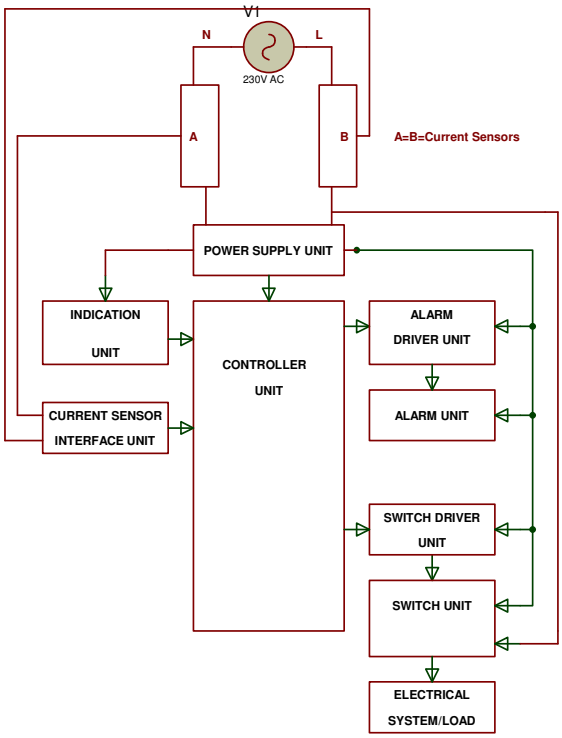

Fig.3: Block Diagram

1. The Power Supply Unit

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the circuit.

2. The Current Sensor Unit

The current sensor unit is used to determine the amount of current passing through the phase and neutral line.

3. The Current Sensor Interface Unit

This unit converts the output signal of the current sensors into low level DC voltage compatible with the controller unit.

4. The Indication Unit

This unit gives a visible indication when an earth fault event occurs.

5. The Alarm Unit

This unit gives an audible alert when an earth fault event occurs.

6. The Alarm Driver Unit

It enables the controller to drive the alarm unit.

7. The Switch Driver Unit

This unit enables the controller to activates/deactivates the switch. It is the interface between the controller and the switch unit.

8. The Switching Unit

The electrical system/load is connected to the phase/Mains line through the switching unit. The unit connects and disconnects the load from the phase/mains line upon receiving control signal from the controller unit.

9. The Reset Unit

On the event of earth fault, the system disconnects the load from the phase line, the reset unit enables the user to re-activate/connect the load back to the phase line after the fault event.

10. The Controller Unit

This unit performs the logic of the entire system.

III. DESIGN METHODOLOGY

The Earth Fault Relay was divided into the following units for simplicity and efficiency. Below are the following units of the design according to the block diagram:

- Power supply unit
- Current sensor unit
- Controller unit
- Alarm driver unit
- Alarm unit
- Indication unit
- Reset unit
- Switch Driver Unit
- Switch unit

1. The Current Sensor Unit

This unit measures the current that flows in the MAINS LIVE and NEUTRAL LINE that supply the LOAD.

Requirements of the Current Sensor Unit

- It should be able to accurately give a voltage signal that is proportional to the current that flow in the LIVE and NEUTRAL LINE.
- Easy principle of operation, easy to use and mount.
- Easy to Bias i.e. it should involve less biasing components
- Availability and Cost Effective

Selection of the Current Sensor Unit

After research, the 45t30A Current sensor module was selected. The module is powered with 5V DC. It can measure up to 30A. Its output ranges from 2.5V to 5V for 0A to 30A linearly.

We use two 45t30 current modules, one for the LIVE LINE and the other for the NEUTRAL LINE of the MAINS that supplies the LOAD.

Below are some of its Features:

The current range is 30A.

Output type: Voltage from 2.5V to 5V for 0A to 30A linearly.

It uses HALL EFFECT method to measure the current and requires 5V DC for power.

Requires No biasing components, as the output connects directly to the Microcontroller.

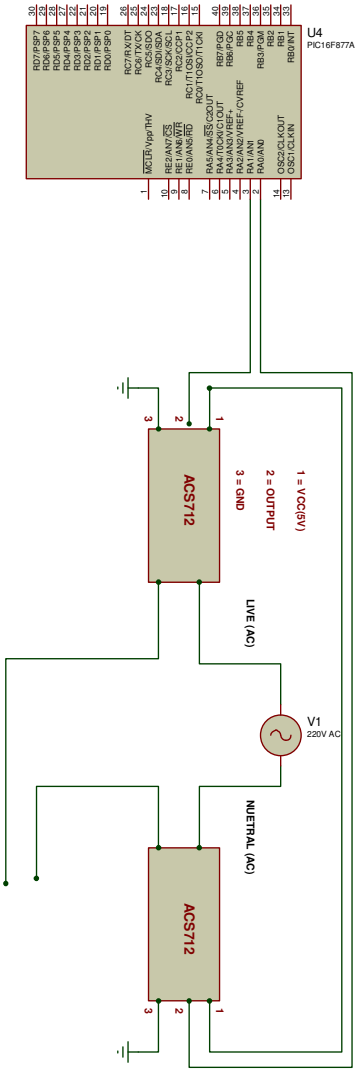

Fig 3.: The interface between the Current sensor and the microcontroller

2. The Switch Drive and Switch Unit

This unit is the interface between the controller unit and the Switch Unit. It Enables the microcontroller to effectively ON and OFF the Switch Unit.

The following components:
Relay (12v, 30A DC).
Resistor.
NPN transistor (BC547).

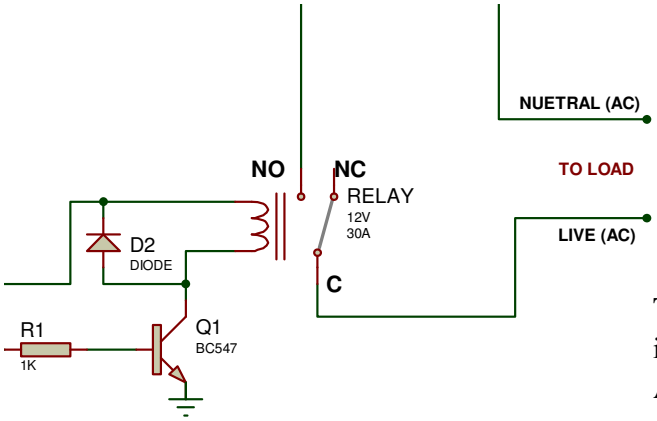

Fig 4: The Switch Driver And Switch Unit

Selection of the Transistor Q1
The choice of Q1 depends on the following parameters:
The nature of the actuating signal (control signal).
The load current demand (collector current).
The supply voltage

The relay current (load current) = Relay voltage/ Relay resistance
Relay voltage=12V (specified)
Relay Resistance= 120Ω (observed)
Relay current demand= 12v/120 = 0.1A i.e. 100mA.
Relay current=transistor collector current.

From the BC547 datasheet, $Ic_{(sat)}$ = 400mA > 100mA (load).
Hfe= 100 to 150; using a Hfe of 120
V_{BE} = 0.7v.

From the switching analysis of a transistor:
$I_{bsat}=I_{csat}$ x hfe;
I_{csat}=400mA; hfe=120;
$I_{bsat}=(400x10^{-3})/120$ = 3.33mA.

Calculating for R_B
$V_p - I_{bsat} \times R_B - V_{BE} = 0$;
Rearranging the equation:
$R_B = (Vp - V_{BE})/I_{bsat}$

From the datasheet of PIC16F877A
V_p = 4.3V;
R_B = (4.3 – 0.7)/0.0033 = 1080Ω. A standard value of 1KΩ was used.

3. The Alarm Unit

This unit servers the purpose of giving an audible indication when the Earth fault event occurs. It is Activated and deactivated by the Controller unit.

Requirements for the Alarm Unit

- An alarm unit with Less biasing components
- Reasonable operating Voltage and current
- Should give a good audible Sound.
- The necessary components should be cost effective and available
- It should be easily interfaced with the controller unit.

Selection of the Alarm Unit

A DC Buzzer Alarm was selected. It operates with 5V to 12V DC, 20mA; it gives a good audible sound and requires less components to bias it; it has a very easy interface that can be incorporated with the controller unit. It is cost effective and readily available.

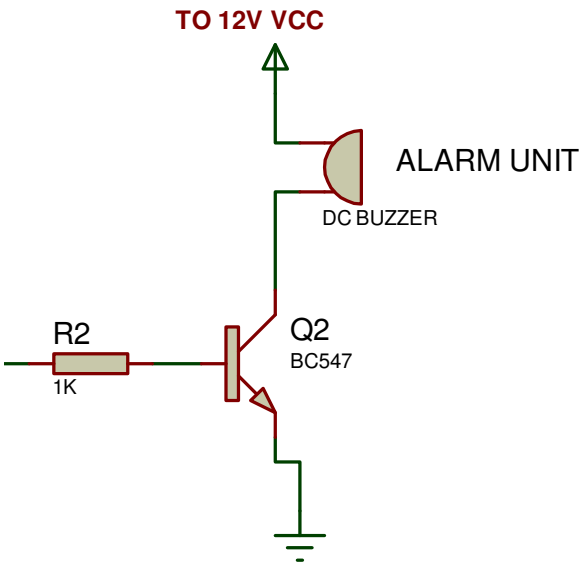

Fig 5: The Alarm Unit

Selection of the Transistor

The choice of transistor depends on the following parameters:

•The nature of the actuating signal (control signal).
•The load current demand (collector current)
•The supply voltage.

The BUZZER current = 20mA

BUZZER current = transistor collector current.

From the BC547 datasheet, Ic (sat) = 400mA > 20mA (load).

H_{fe} = 100 to 150; using a H_{fe} of 120

V_{be} = 0.7V.

From the switching analysis of a transistor:

$I_{bsat} = I_{csat}$ x hfe;

I_{csat} = 400mA;

Hfe = 120;

$I_{bsat} = (400x10^{-3})/120 = 3.33mA$.

Calculating for R_B

$V_p - I_{Bsat} \times R_b - V_{be} = 0$;

Rearranging the equation:

$R_B = (V_p - V_{BE})/I_{Bsat}$

From the datasheet of PIC16F877A

$V_p = 4.3V$;

$R_B = (4.3 - 0.7)/0.0033 = 1080\Omega$. A standard value of 1KΩ was used.

4. Principle of Operation

According to the circuit diagram, When the switch is ON, the power supply unit provides 5V Dc to the Circuit, the microcontroller initializes its internal registers. Then microcontroller outputs HIGH(5V) at PIN33 to Activate the SWITCH. Then it performs ADC conversion on the voltages at PIN2 and PIN3. it Compare the returned values, if the result of the comparison is true, it waits and performs ADC conversion again, but if false, it outputs LOW(0V) at PIN33 to deactivate the SWITCH, outputs HIGH at PIN27 to activate the ALARM Unit and also outputs HIGH at PIN30 to activate the indication unit. When the user presses the RESET button, the microcontroller outputs a LOW at PIN27 and PIN30, then a HIGH at PIN33. the process starts all-over again.

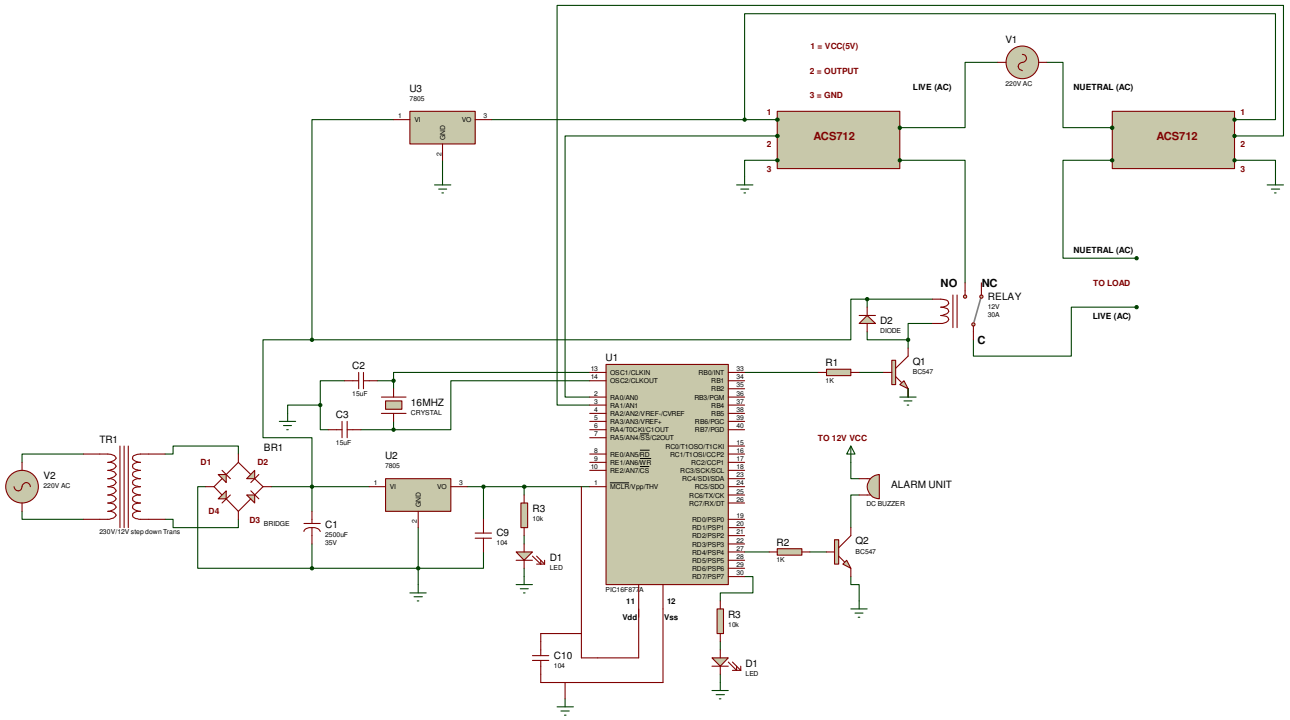

Fig.4: Working Circuit

IV. RESULT

This System is designed to prevent faults in electrical systems due to earth leakage current. The protection of electrical system is required to maintain any device in operation without failure.

There are various types of protective devices used in Power Systems. The knowledge of protective devices helps to use them smartly and avoid system breakdown. Earth leakage current gives rise to heat generation and progressive failure of insulation which leads to earth faults & sparks. The Earth Fault Relay detects the leakage current well before they cross threshold limit.

Finally, the system was subjected under various tests to see if it will trip seeing abnormal current; the circuit was successfully energized without a problem.

V. CONCLUSION

A successful attempt has been made to design and implement an Earth Fault Relay using locally available material. The system is capable of detecting Earth Leakages in devices. The completed work had been tested and worked satisfactory.

ACKNOWLEDGEMENT

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