Providing a Method for Preventing Accidents while Energizing the Neutral

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Abstract: The problem of neutral energizing in electric power distribution networks always affects these companies and in some cases, it leads to financial damages and even electrocution (electrical shock). The electric power distribution lines may cause hospitals, power plants, factories, military centers and sometimes distribution networks and subscribers to confront the problem of neutral energizing in its distribution network. Owing to the fact that no solutions has been provided to prevent the neutral energizing in electricity distribution networks, this study has endeavored to first assess the results of this problem and then, solve it by proposing a device that is capable of measuring the voltage between neutral and ground. This device cut off the main power switch before the occurrence of any accidents in case the voltage exceeded 50 volts (electrocution threshold voltage according to VDE standard).

Keywords: Neutral Energizing, Electrocution, Electric Power Distribution Networks, Voltage

1. Introduction

Electrocution is one of the incidents that are increasing along with the industrialization of today's human life and regardless of its therapeutic aspects as well as social and psychological outcomes, it is remarkably important in terms of legal and judicial. This is obvious as we are witnessing unfortunate work events of this type every day among the labor class and our society (Lutfun Nahar Nizhu, 2020). Over thousands of deaths have been occurred annually around the world due to the electrical injuries. In children, home appliances or unprotected toys cause the most electrical damages while among adults, particularly those workers who are working with electrical equipment, these damages are considered as common work incidents. Hence, it will be worthwhile to investigate the various aspects and reasons for this issue (Antonio De Donno, 2019). The majority of people believe that the possibility of damage and the risk of electrocution will be eliminated by disconnecting the fuse and electricity but this action merely causes the phase to go

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out of the circuit while the neutral exists in the network. Unlike most people's belief, neutral has electricity in the distribution network that leads to problems such as the risk of electrocution for humans and animals and also the damage to the electrical equipment like neutral energizing. It is essential to note that neutral energizing cannot be even detected by residual-current devices. In most cases, the risk of electrocution will be significantly augmented in places next to the utility poles and during the rainfall when the humidity around the utility pole is high (Bharath Varsh Ra, 2019). The neutral wire is one of the important wires in the electricity supply system of a city that has no danger to people and can be touched without electrocution. As mentioned, the electric current will not be established until it has no return path to the source. In fact, the neutral wire is used to create this circuit or closed path and also it returns the output currents of the electrical device to the generator. The neutral wire can be usually identified by white or gray insulation (Vinicius P. Suppioni, 2016). Most electrical devices have metal bodies. Since metals are electrical conductors, the risk of being electrified always exists for them. To solve this issue and to prevent possible problems, an earthing system and all equipment with the metal body have been used in buildings. In order to keep individuals safe when they are working with electrical equipment, the body of the device is usually connected to the water pipe by a wire and the water pipe is in contact with the humid parts of the ground. This wire is called earth wire which should be connected to the earth, well, but instead, it is connected to the water pipe for economization purposes. This wire is insulated with green and yellow colors. Unbalance of the current in three-phase system and the current`s passage through the neutral wire has a voltage toward the ground (earth) which is unsafe if exceeds the permissible limit and there is the possibility of electrocution if the consumer has contact with the neutral wire. A high unbalanced network load will create an undesirable condition in other components of the network such as transformers (Amirreza Naderipour, 2019). Due to the lack of coordination between the relevant organizations with the electricity department or defect in the connection of neutral and earth, this connection will be cut off which is remarkably dangerous as voltage will rise up to 380 volts in this situation. There are a huge number of deaths and financial losses annually that often affect electricians and people; therefore, it is essential to provide an approach for timely detecting and disconnecting the electricity prior to the occurrence of an incident.

2. Research Methodology

This study was a quantitative research. Electrocution and unbalanced load, two of the most widely used and challenging areas in the electricity industry, have been investigated in this study. Some of our findings have been collected through the study of previous research and the use of library research while others were acquired according to the experiences of professionals in this filed.

The reasons for neutral energizing in the network

- In case of short circuit of phase and neutral in the distribution network, neutral becomes electrified (sometimes switches and fuses do not detect)
- In the distribution network, the neutral must be connected to the earth. If its earthing is disconnected for any reason, the neutral will be electrified with the slightest unbalance in each of the three phases.
- It can happen if one of the phases in the distribution network is connected to the earth (G. Carpinelli, 2019)

Calculation of Neutral Current

In this section, losses in balanced and unbalanced states of a network with pure and centralized ohmic load at one point have been investigated and compared (loadsRuben Lliuyacc, 2017).

The neutral current value would be equal to (1) or (2):

(1) $In = \sqrt{(In)_x^2 + (In)_y^2}$

(2) $In = \sqrt{I_1^2 + I_2^2 + I_3^2 - I_1 I_2 - I_1 I_3 - I_3 I_2}$

If currents are balanced, then the neutral current would be 0 and the amount of losses would be calculated as follows:

(3) $\text{Balanced Losses} = 3RI^2 = \frac{R}{3}(A = (I_1 + I_2 + I_3)^2$

If currents are unbalanced, the amount of losses would be obtained by (4) with the assumption that the cross-section area of phase wires is equal to:

(4) $\text{Unbalanced Losses} = RI_1^2 + RI_2^2 + RI_3^2$

The difference of losses in balanced and unbalanced states is equal to:

(5) $\frac{2}{3}R(I_1^2 + I_2^2 + I_3^2 + I_1 I_2 - I_1 I_3 - I_3 I_2)$

Since the following inequality is always true, the above relationship is always positive and losses in the unbalanced state are higher than the balanced state. This equation does not consider the losses in the neutral wire. If the cross-section area of the neutral wire is considered to be equal to phase wire, the losses of neutral wire (equations (6) and (7)) are added to it and equation (5) would be reformulated as (8):

(6) $I_1^2 + I_2^2 + I_3^2 \geq I_1 I_2 + I_1 I_3 + I_3 I_2$

(7) $RI_n^2 = R(I_1^2 + I_2^2 + I_3^2 + I_1 I_2 - I_1 I_3 - I_3 I_2)$

(8) $\frac{5}{3}R(I_1^2 + I_2^2 + I_3^2 + I_1 I_2 - I_1 I_3 - I_3 I_2)$

(9)

Damaging Regarding Neutral Energizing

Neutral energizing causes electrocution to everyone even electricians, because they trust the fuse cut off while there is the voltage between neutral and earth, which may lead to the electrocution. In some situations, particularly during rainfalls, the ground is electrified and therefore a voltage will be created between the feet (step voltage) of people and animals who go through that path which causes electrocution.
Neutral energizing causes electrical oscillation in the distribution network. These oscillations can cause damages to the electrical equipment especially in the switching of the current. Also, if the neutral is electrified and ruptured by the transformer, the voltage will rise up to 380 volts, which may burn out the electrical equipment placed in this path (Billel Kahiaa, 2018).

Explaining the proposed method for a power outage during neutral error
Detecting the error of neutral energizing in the network and on-time power outage is considered as a method to prevent the occurrence of the incident. In this approach, the proposed device becomes able to timely detect the error and disconnect the power until the time when professionals come to solve the problem.

Circuit Description
A. Rectifier Circuit
The purpose of the rectifier is to convert AC voltage to DC. 4 1N4007 diodes have been used to implement this section. In addition, a fuse that can withstand between 100 and 500 mA have been employed to protect the circuit.

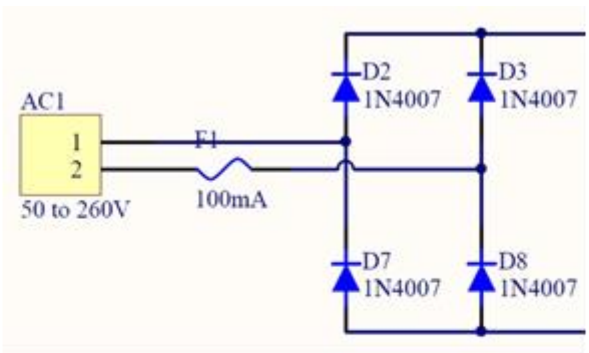


Figure 1. Rectifier circuit
In Figure 2, the method of circuit rectification has been completely demonstrated with details.

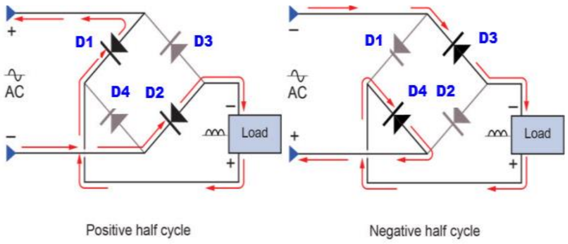


Figure 2. Circuit rectification

It can be seen that Figure 2 illustrates the rectification method as well as the series and parallel condition of diodes. Also, the voltage rectification diagram is shown in Figure 3.

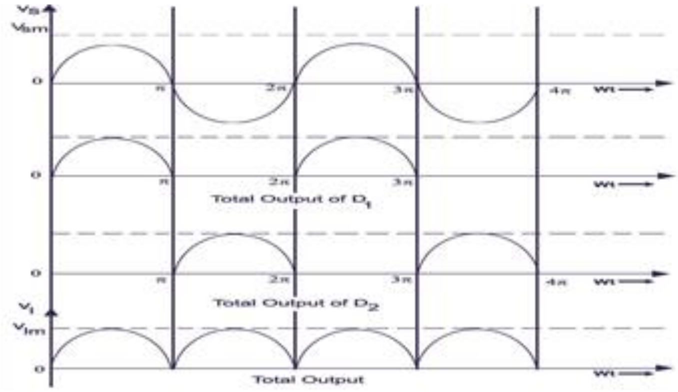


Figure 3. Rectification diagram

B. Filter Circuit

The purpose of a filter circuit is to omit the oscillation in the waveform to achieve a smooth voltage. In this paper, a filter or filter circuit ∏ was used. The filter circuit is by far the most powerful filter for omitting the oscillations.

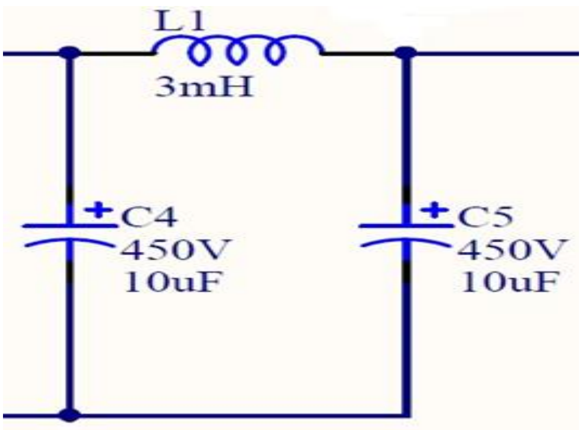


Figure 4. Filter circuit

The input voltage between 50 to 260 AC is the alternating current, which can convert to 70 to 367 DC after rectification and filtering. Owing to the fact that the maximum filter voltage is 367 V, the capacitor used in the filter circuit should have a voltage greater than 367V to be protected from damage. The operation of rectification will conduct better with the higher capacitance of capacitor and inductor in the filter circuit, but the excessive increase of the capacitor capacitance creates two problems as follows:

- The dimension of the capacitor will become too large due to its high voltage
- It may cut-off the instantaneous current and create a spark when the circuit is plugged in which in turn, it can burn fuses or rectifier diodes

However, some solutions have been suggested for this problem such as applying a series resistor before filter circuit and parallelizing capacitors with rectifier diodes to make the passage of instantaneous current possible and prevent any damages to diodes. In order to select the appropriate inductor, the current value of circuit should be considered since the circuit current passes through the inductor coil and an inadequate cross-section area of its lacquer wire will lead to voltage drop and inductor burnout. Figure 5 shows the rectified wave, oscillation voltage and the role of the filter circuit.

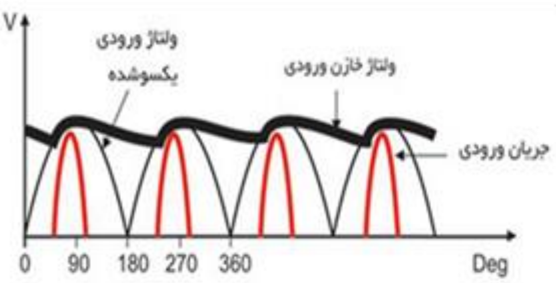


Figure 5. The rectified wave

C. Control Circuit

The main task of the control circuit is to produce the PWM waveform. The role of this waveform and its pulse width is remarkably important since the growth of pulse width increases the output voltage and also the reduction of pulse width will reduce the output voltage. The type of control circuit used in this study was the transistor. Its main transistor was MJE13003 whose VCE is able to withstand 400V voltage. The control circuit measures the output voltage level with the help of feedback and increases its cycling through the voltage drop at the diode output. This can increase the voltage and compensate for the voltage drop at the output.
There are two reasons for the voltage drop at the output: the growth of the consumer current at the output and the reduction of voltage at its input.

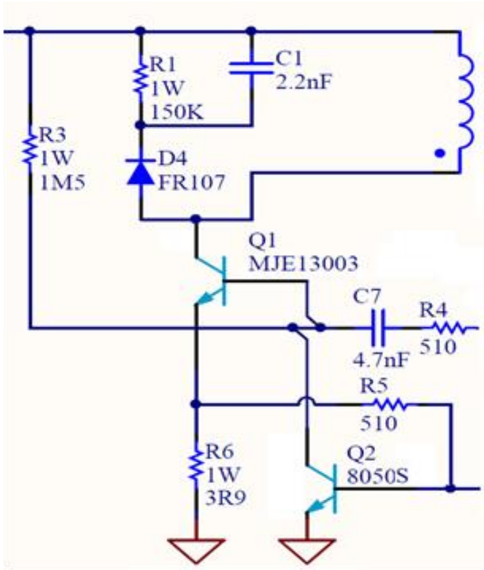


Figure 6. Control circuit

D. Snubber Circuit

A snubber circuit is a capacitive, ohmic and diode circuit used to protect electronic circuits against voltage changes over time.

During on and off of the instantaneous current, due to the square PWM wave of transformer coil, it stores some energy which is then calculated as the instantaneous current inside the transformer coil. If the current in the coil is cut-off instantaneously, the energy will become 0 momentarily. The voltage of the inductor, which is called the needle voltage, is obtained by deriving the inductor current changes over time. Due to the small-time period and slope, this needle voltage has experienced very changes that can easily damage its adjacent parts.

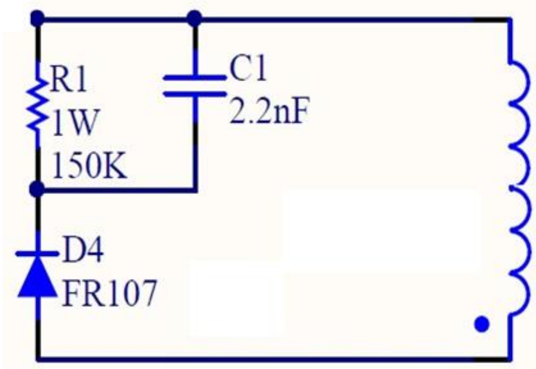


Figure 7. Snubber circuit

2-2. the Performance of Snubber Circuit

This circuit has a capacitive nature and can derive from voltage changes and then create a capacitive current that discharges the intense instantaneous current in the inductor. The snubber circuit is responsible for protecting the components and it is used to improve the performance of the circuit.

2-3. Transformer

The most important merit of switching circuits is the frequency growth and shrinkage of the transformer dimensions. In this circuit, the transformer has been designed using EI Expert software, which has EI core with EE19 standard.

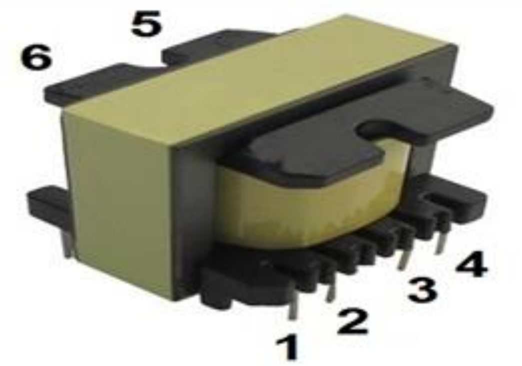


Figure 8. The overview of transformer input and output

2-4. Transformer Specifications

- The number of primary rounds: 130 rounds, 0.16 mm lacquer wire
- The number of secondary rounds of the main output: 9 rounds, two pairs of 0.6mm lacquer wire
- The number of secondary rounds of subsidiary output: 10 rounds, 0.2mm lacquer wire

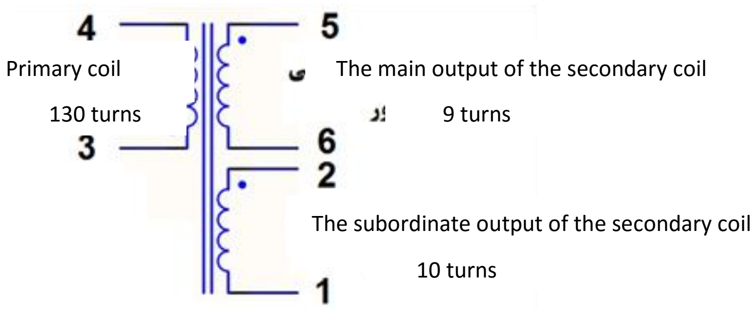
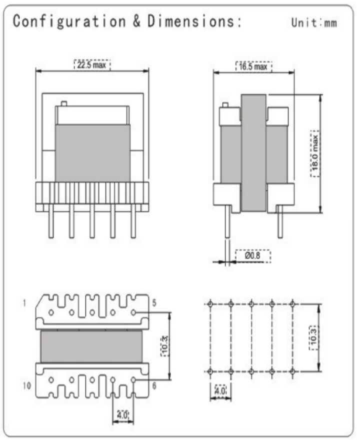


Figure 9. Coil specifications



General scheme and transformer dimensions with EE19 Core

2-5. Transformer Coiling Steps

Step 1: Wrapping the primary coil around the pulley
Step 2: Insulation
Step 3: Wrapping the secondary coil of the main output
Step 4: Insulation
Step 5: Wrapping the secondary coil of subsidiary output
Final step: Insulation and insertion of EI core and then soldering lacquer wires to the basis of the transformer.

2-6. Feedback Circuit

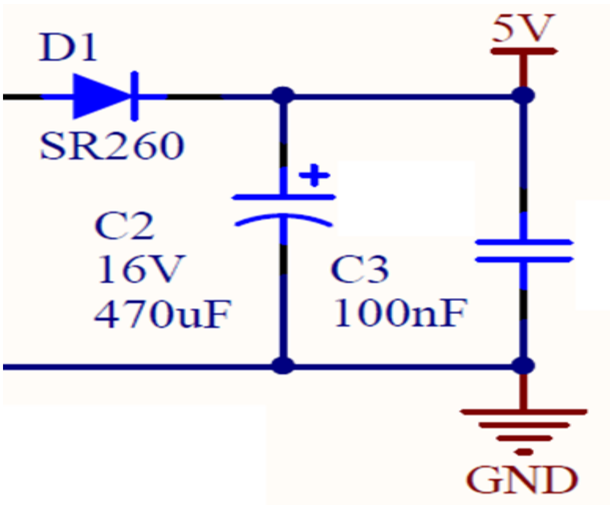
The feedback circuit is employed to compensate for the drop or increase in the output voltage so that it can continuously adjust the output voltage to a constant value. In the feedback circuit, a sample is taken from the output of the circuit and then sent to the control unit to adjust the PWM.
This section must be isolated to prevent the infiltration of high input voltage to the output when components are burnt. In this research, Opto-coupler (Opto-isolator) 817 was applied to isolate the input and output.
The LED part of the Opto-coupler is connected to the circuit output by a number of components and its phototransistor is connected to the transistor base in order to provide the output voltage of the transformer as the feedback for switching part. Therefore, the IC becomes aware of the voltage changes in the output and adjusts its performance.
The voltage threshold is specified by Zener diode 9. In fact, the output voltage of the circuit is determined by this diode. According to the voltage drop in the LED of Opto-coupler, the output voltage is approximately 1V higher than the voltage of the Zener diode. Hence, if 12V output is desired, Zener diode 11.1V should be used and 5V output should be provided as well as the application of Zender diode 3.9V. It should

be noted that Zener diodes do not exist for all ranges of voltages and they have specified values. Furthermore, Zener diode with 0.5 watts' power is also enough for the intended circuit.

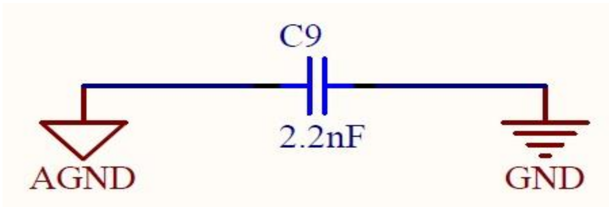
Output Rectifier and Filter

This circuit rectifies its input square waves using diode D1 and filters it with capacitors C2 and C3.

The capacitors C2 and C3 are for eliminating the high-duration and low-duration oscillations, respectively.



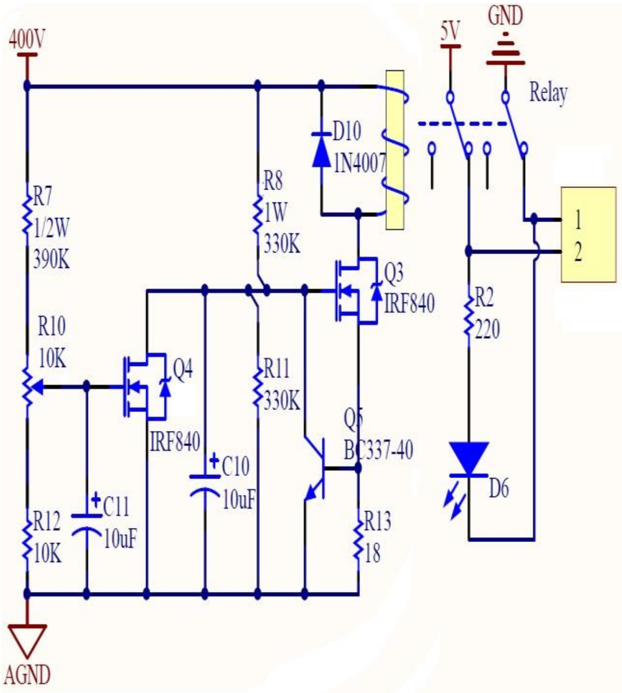
The Y-cap capacitor is placed between primary and secondary capacitors which pass the current if its voltage exceeds the limit. A capacitor is created in the gap between a primary and secondary capacitor which can be charged up to several kilovolts during the operation and its discharge may cause a damage to the circuit. The Y-cap capacitor does not allow this capacitor to be charged excessively. The amount that can be considered for this capacitor is from 1 to 10 Nano Farad depending on the capacitance of the capacitor, which should have a voltage of more than 400 volts.



2-7. Circuit Breaker

The circuit breaker allows users to specify the lowest voltage for the device although the minimum value of this voltage is 40V. The output of the circuit is interrupted by relay at input voltages lower than the specified voltage.

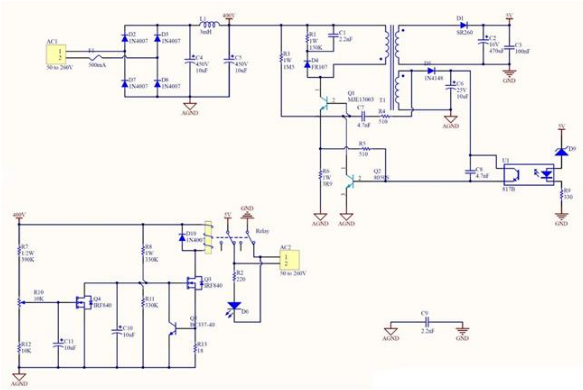
The breaker voltage is adjusted using potentiometer R10.
In this circuit, MOSFET has been applied to omit the need for current in the circuit because the input voltage goes up to 400 volts and at this voltage, even lower current requires a lot of power. The utilized MOSFETs should be able to withstand over 400V of VDS voltage in order to keep from damage.
A 12V relay has been employed in this circuit. This relay switches on from about 10V voltage and remains on up to the user-adjusted voltage.



2-8. Specifications of Device Operation (working)

1. Detecting neutral energizing in the distribution network
2. Measuring the neutral voltage by earth voltage and determining the danger limit of this voltage
3. Alerting and disconnecting the neutral and phase together in the consumer network if the neutral voltage passes the danger limit
4. Enhancing the safety in distribution networks from their producer to consumers
5. Preventing the risk of electrocution and the dangers caused by damaging the electrical equipment

Circuit Overview



Conclusion

The problem of electrical network energizing is caused or aggravated by the technical defect of equipment, wrong design of distribution network, human error, sabotage and environmental factors such as rainfall and humidity. The neutral energizing in the network leads to the electrocution and cause some damages to the equipment; hence, we should be able to detect this problem promptly and then completely disconnect the neutral and phase of the network. Our goal was to build a device that continuously could compare the neutral voltage with earth base voltage. The neutral voltage up to 50V was considered as the low-risk () because if the voltage exceeded from 50V, the device made an alert and cut-off the electricity. In hospitals and other sensitive centers where electricity should not be cut-off, it is possible to send an alarm for technicians to make them aware of the problem so that they can solve it. It is essential to note that the design of this device is adjustable in such a way that you can select and adjust the limit of alarm voltage and dangerous voltage. This device can be used industrially in three-phase circuits, in power distribution networks and in homes by consumers. It is obvious that using this method, the problem will be solved sooner and loss of life and financial loss will be avoided.

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