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Leakage and Short Circuit Current Localization in Electrical Networks: Diagnosis and Prevention Techniques

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Abstract: Leakage and short circuit currents are common problems that can occur in electrical networks, including those found in household applications. These issues can lead to energy waste, leading to downtime in industries, damage to equipment, and even pose a risk of electrical shock or fire. Therefore, it is essential to identify and localize these issues in order to resolve them quickly and prevent further damage or hazards. RCD (Residual Current Device) and RCBO (Residual Current Circuit Breaker with Overcurrent Protection) are commonly used as safety devices to protect against leakage current and short circuit in electrical systems. However, these devices have limitations in their applications. This paper discusses the challenges associated with the diagnosis and prevention of leakage currents majorly and also short-circuit currents in electrical networks. Additionally, the survey paper explores prevention techniques using IoT (Internet of Things) and machine learning techniques to overcome these limitations.

Keywords: Leakage Current, RCD, RCBO, Micro-controller, IoT, Machine Learning.

I. INTRODUCTION

Electricity is an integral part of our modern life, and it plays a critical role in powering our homes, businesses, and industries. However, with the use of electrical devices, there comes a risk of electrical hazards that can cause injury, damage, and even death. One of the hazards associated with electricity is leakage current, which can lead to electrical shock, fire hazard, damage to equipment, and increased energy bills.

Leakage current occurs when electrical current flows through unintended paths or insulation faults. In the home, leakage current can be caused by earth faults, which occur when a live conductor comes into contact with an exposed conductive part, such as a metal appliance or water pipe. Earth faults can be caused by a variety of factors, including poor wiring, faulty appliances, and damage to electrical equipment. To prevent the hazards associated with leakage current, various safety devices have been developed, including residual current devices (RCDs) and residual current circuit breakers with overcurrent protection (RCBOs). These devices are designed to quickly detect and disconnect the power supply in case of an earth fault, thereby preventing the risks associated with leakage current and short circuits, but there are limitations to using the RCBO devices such as false tripping, compatibility, regular maintenance, slow response time, cost majorly it shut down the whole part of the electrical network. This paper describes a method to detect the location of leakage and short-circuit currents in an electrical system without the need for RCBO devices.

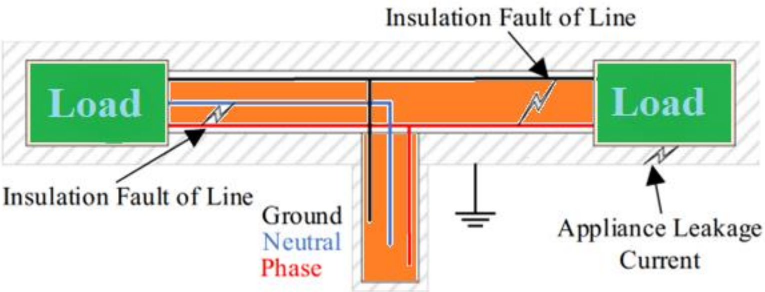

Fig.1. Excess of leakage current occurs

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II. LITERATURE REVIEW

An automated system has been developed to detect MCBs with leakage currents. The system instructs the user to open the specific MCB(s) with leakage currents and close the RCD to restore the power supply (Muralindran Mariappan, 2020). An electrical consumer panel is an integral part of an electrical supply system that distributes power to subsidiary circuits while providing protection through fuses or circuit breakers. Fuses are designed to prevent excessive currents from causing further damage to the system by opening circuits when necessary (Singh et al., 2013). In a single-phase electrical consumer panel, there are several Miniature Circuit Breakers (MCBs) of different rated currents and one or more residual-current devices (RCDs). MCBs are electromagnetically protected devices used in various settings such as houses, railways, and industries to supply electricity (Kumar, 2013). As Kelvin Boone stated in his article "A Guide to the Selection of Electrical Cable and Breakers," MCBs can function as ordinary switches and circuit breakers to protect against overload and short-circuit currents

III. DEVELOPMENT OF A DEVICE TO MONITOR THE LEAKAGE CURRENT

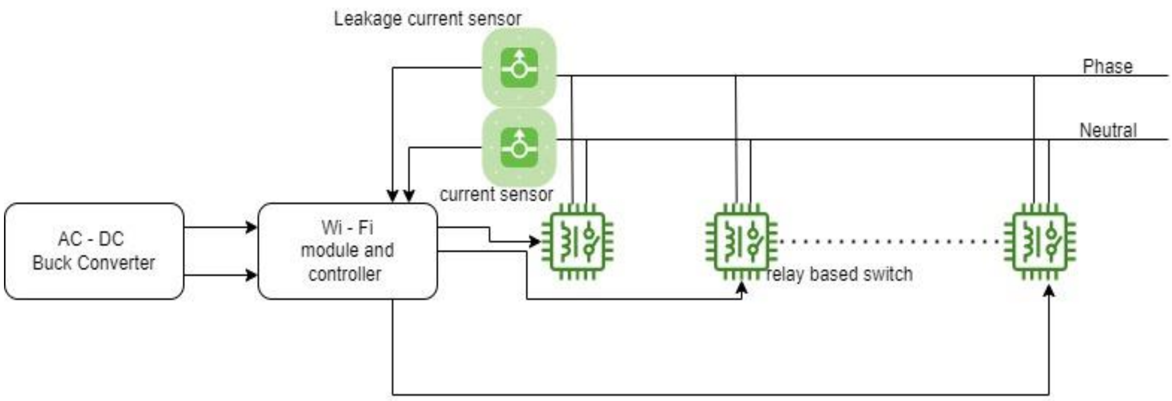

Fig.2. Hardware requirements

AC-DC Buck Converter: An AC-DC buck converter is an electronic device that is used to convert an alternating current (AC) input voltage to a direct current (DC) output voltage that is lower than the input voltage. It works by using a series of switches, typically made of metal-oxide-semiconductor field-effect transistors (MOSFETs), to control the flow of current through an inductor. During each switching cycle, the input voltage is applied across the inductor, which stores energy in the form of a magnetic field. When the switch is turned off, the energy stored in the inductor is released and the output voltage is obtained. It gives step down the input voltage while minimizing power loss. This makes it useful for applications to work with operating ranges.

Wi-Fi module and controller: A WiFi module is a device that enables wireless communication over a local area network using the Wi-Fi standard. It includes a microcontroller with integrated WiFi capabilities, an antenna, and other necessary components. It is commonly used in IoT devices such as smart home appliances, security systems, and environmental sensors to connect to the internet or other devices on the same network without cables. Controllers are devices used to manage and regulate the operation of electronic systems, including WiFi modules. In some cases, WiFi modules have built-in controllers, while in others, the controllers may be separate devices depending on specific requirements and capabilities. Here the use of this Wi-Fi controller is to sense the data from the sensors and send it to this cloud for further analysis and also taking action.

Leakage current sensors: Leakage current sensors are used to detect and measure small amounts of current that are "leaking" from an electrical circuit to ground or other unintended conductors. These sensors work by monitoring the difference in current flow between the "line" and "neutral" conductors of an electrical circuit. Any current that is flowing to the ground or other unintended conductors will result in an imbalance between the current flowing in the hot and neutral conductors, which can be detected by the sensor.

A microcontroller-controllable relay is a device that allows a microcontroller to switch on or off a high-voltage circuit using a low-voltage signal. It consists of a control circuit and a switching circuit, which are isolated from each other to provide safety and prevent interference. The control circuit is connected to the microcontroller and sends a low-voltage signal to activate the switching circuit, which is connected to the high-voltage circuit. This type of relay is commonly used in automation systems and electronic devices to control various processes and operations.

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IV. WORKING METHODOLOGY

The system initially checks the device status to measure the incoming current from the leakage current sensors. If there is an abnormal current in the phase, the system determines it as an over-current short circuit fault. The leakage current sensor works by measuring the magnetic field generated by the current flowing through the conductor, which induces a voltage in the sensor proportional to the current. If the measured leakage current is abnormal, the system checks for resistive and capacitive faults.

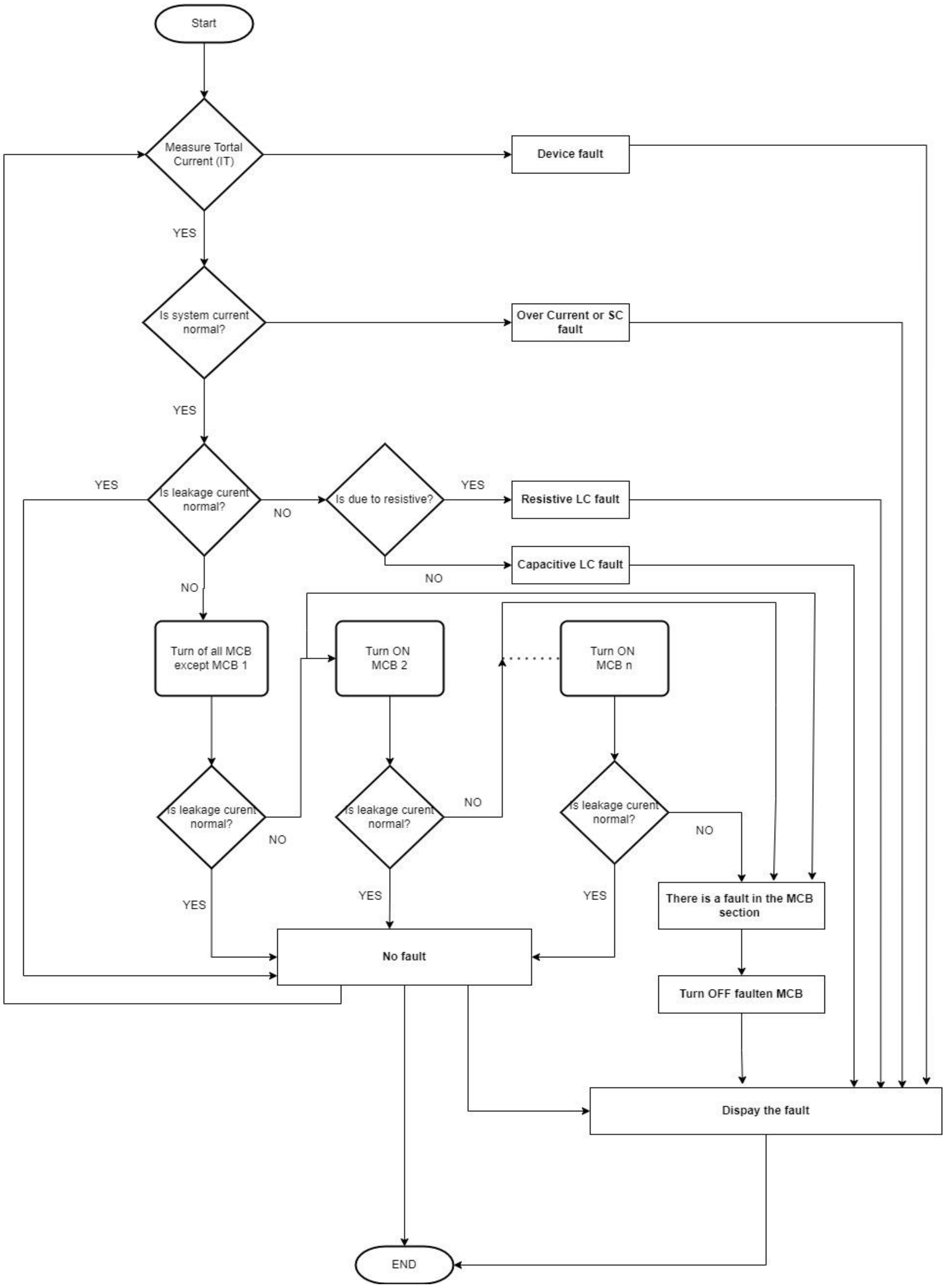

Fig.3. Working flowchart

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Measuring resistive and capacitive faults can help identify potential safety hazards and take corrective actions to prevent them. For example, a resistive fault in an electrical appliance may be due to a damaged wire that can be repaired or replaced to prevent further issues.

A capacitive fault may be caused by faulty insulation or improper grounding, which can be fixed to ensure the safe and proper operation of the electrical system. Therefore, measuring resistive and capacitive faults, along with leakage current, can help ensure the safe and reliable operation of household electrical systems and appliances.

If the leakage current is detected as abnormal, the system switches on and off a series of controllable relays to measure the leakage current. To begin with, all relay-type MCBs are switched off, and the first MCB is switched on to measure the leakage current. The system then measures the leakage current of all MCBs one by one, and if the measured leakage current is found to be higher than the threshold level, the respective MCB is turned off.

V. ALGORITHM TO MEASURE THE FAULT

Step 1: START
Step 2: Check device status to measure incoming current from leakage current sensors
Step 3: If abnormal current in phase, determine as over-current short circuit fault
Step 4: Use leakage current sensor to measure magnetic field generated by current flowing through conductor and induce voltage in sensor proportional to current
Step 5: If measured leakage current abnormal, check for resistive and capacitive faults
Step 6: If resistive or capacitive fault detected, take corrective action to prevent safety hazards
Step 7: Switch off all relay-type MCBs
Step 8: Switch on first MCB and measure leakage current
Step 9: Measure leakage current of all MCBs one by one
Step 10: If measured leakage current above threshold, turn off respective MCB
Step 11: Repeat steps 8-10 until all MCBs have been measured
Step 12: END

VI. CONCLUSION

The paper explores the challenges posed by leakage and short circuit currents in electrical networks, which can result in damage, energy waste, and hazards like electric shock or fire. To address these issues, the paper proposes a non-intrusive method to detect and locate such currents, which involves using a combination of hardware components like an AC-DC Buck converter, Wi-Fi module and controller, leakage current sensors, and a microcontroller-controllable relay.

The collected data is then analyzed using machine learning algorithms to identify the location of faults and take appropriate action. This approach has the potential to overcome the limitations of RCBO devices, including false tripping, regular maintenance, slow response time, and high costs. Moreover, the incorporation of a Wi-Fi-enabled panel could allow stakeholders to collect electricity consumption data from customers, thereby benefiting the smart grid.

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