Real-Time Monitoring and Control of Urban Power Distribution Systems using Air Circuit Breakers and LabVIEW: An Integrated Approach

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***Abstract*:** In urban areas, electricity is required for different types of work, such as transportation, water supply, communication networks, the operation of waste treatment plants, garbage recycling factories, and sewage disposal units. Works cannot be completed without electricity, which helps to promote hygiene and environmental preservation. Consequently, distribution grids may get overloaded and congested because of high population concentrations in towns. Such areas with high demand have problems relating to low voltage drops resulting from overloading transformers with cables overheating, hence affecting the reliability as well as efficiency of the system. To avoid such errors, ACB is used. The purpose of ACBs is to detect short circuit faults quickly before tripping within milliseconds, thus isolating damaged parts from the rest of the network. In this proposed work, ACB is used to detect short circuits and turn off the power supply using LabVIEW. A G Web Development Software is a programming environment that can be used to create a web. Through this the data can be viewed on the website. Alert processes and notifications on the website inform of its danger. ACB can be turned on by providing power to the closing coil and spring charge motor signal through the ACB LABVIEW website. This way, data can be viewed online, and hence, data can be accessed from anywhere.

Keywords*— *ACB, LABVIEW, G Web Development Software, closing coil, spring charge motor

1.INTRODUCTION

Urban electricity companies face unique challenges such as safety, increased power demand, right of way, and cost in the context of power distribution in urban areas [1]. The abbreviation ACB is commonly used to mean an air circuit breaker. It makes use of compressed air so as to quench the arc formed whenever the contacts open during a fault condition in an electrical circuit. They are usually used for overcurrent and short-circuit protection in medium to high- voltage applications [2]. It recognizes and mitigates power- related dangers such as short circuits and under voltage. These ACBs usually employ both magnetic and thermal tripping mechanisms to sense the occurrence of short circuits. In the case of a short circuit, the high current flowing through the circuit creates a strong magnetic field, which triggers the magnetic trip unit of the ACB to quickly open contacts by means of this magnetic trip unit, interrupting the circuit before

further damages occur. It also detects excessive heat generated by overcurrent in case of overloads in the electrical system, which causes it to open contacts, which, therefore, protects against overheating and fire propagation risks [3]. For example, low supply voltage can cause most single-phase motors to stall or burn up, so it may be necessary to design for such conditions with equipment protection to provide safe operation under these circumstances [4]. Some ACBs may have under-voltage release mechanisms that protect against voltage dips or sags below a set threshold value. When the voltage drops below a specific degree. The ACB is driven into tripping mode using its under-voltage release mechanism, thereby isolating from the source and preventing any damage to equipment during low-voltage conditions [5]. Apart from that, ACBs protect against overload currents as well.” Overload conditions result from current flowing through the circuit, which is in excess of its rated capacity for an extended period. ACBs continuously monitor the current flow, and if overload is detected, the thermal trip unit will activate, which leads to tripping of the ACB and opening of contacts to prevent overheating and damage to circuit components [6]. When a fault occurs, the system can trip the affected portion of the network through an automatic operation, hence isolating it from further damage and guaranteeing personnel and equipment safety. The remote monitoring ability of operators by automatic control systems allows them to monitor and manage other components found in power distribution systems, such as ACBs, from one central location. Therefore, quicker response times would result because of isolated failures as well as immediate management via better resource allocation and personnel deployment during emergencies [10]. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) can automatically control air circuit breakers (ACBs) by interfacing with their control systems. Some of these parameters include voltage, current, power usage, and temperature, which can be monitored using sensors and transducers attached to these devices. It is also important to note that this capability allows continuous health and performance monitoring of such electrical systems. This system can either run on LabVIEW applications located remotely or connected to a central monitoring station where they give operators authority over ACB distantly. Timely reactions are thus promoted due to operational efficiency

thereby increasing their usefulness in times when they matter most [7,8]. LabVIEW program requires setting up appropriate communication protocols between LabVIEW and ACB hardware (Modbus, Ethernet/IP, Profibus). Lastly, we must implement some control logic within LabVIEW so as to monitor and control our ACB based on the input signal. Such notifications of alarms/messages should only be dispatched if a specific fault is detected or there is a change in status that was pre-defined for the ACBs. An update mechanism for the LabVIEW server status of ACB should be implemented [9]. Therefore, regardless of the manufacturer or model, it can be easily integrated with other types of ACBs and equipment. With the modular architecture of LabVIEW, engineers can realize scalable control systems that will accommodate expansions or modifications anticipated in the future. The components are easy to add, remove, or replace without disrupting the normal features of a system, thereby providing flexibility and adaptability toward changing needs [11]. Creating and managing websites are two critical functions of web designing software. Nevertheless, “A G Web Development” Software is a robust coding platform that aims to ease the process of dynamic and interactive web application development. Developers can use this software to come up with websites that not only display data but also capture user’s attention by including various functionalities. It is important to note that one essential attribute of such kind of software is its inclusion of alert procedures as well as notifications; these are aimed at improving user experience through the timely provision of information, developing alerts on potential danger or highlighting important changes [12].

2.LITERATURE REVIEW

Against instantaneous current surges and longer-term over-current conditions[13] the manual tripping mechanism serves as a protective measure. On an average circuit breaker, this study has developed a monitoring control scheme based on the Arduino Mega 2560 embedded microcontroller and Ethernet Shield for IoT integration [14]. This technique is called dynamic analysis which was used to design that circuit- breaking mechanism. It started with precise multibody modeling for an optimal design of the circuit breaker [9]. The Ishikawa diagram shows the root causes of various faults during its lifespan in ACB. ACB is vital for power system protection; thus, reliability becomes crucial [15]. Therefore, designing for under-voltage and over-voltage protection to protect/extend the life span of home/office/industry equipment [16]. The paper [17] suggests developing an Arduino-based prototype for voltage fluctuation protection systems that could serve host appliances from over or under- voltage effects. The 8051 family’s 8-bit microcontroller fully controls the system. When a password is entered through a keypad, a relay opens or closes the circuit breaker, showing by lighting up a lamp [18]. More so, it identifies common- cause failures as well as temporary and permanent faults together with their clearing times, backup protection operation, and relay mal-trips, among others [19]. Circuit breakers can be automated via a motorized scheme that is microcontroller-based [20]. An automatic circuit breaker monitoring system for monitoring the control circuit of a circuit breaker is proposed. The system’s design is such that it supports the deployment of data retrieved from it to drive system-wide applications [21]. The reliability assessment and improvement process for ACB involves the investigation and elimination of root causes of failure using different relevant techniques [22]. It evaluated contact arrangements of low CBC reed relay VI contact switches involving air-insulated contractors [23]. FCLCB has series resonance with current limiting and breaking advantages, as well as better fault current limiting properties than other previous FCLs and SSCBs for application in electrical power distribution networks to J150+ aircraft DAS/FADEC [24]. Embedded systems research and development embraced MODBUS/TCP industrial Ethernet protocol. Primary functions are real-time scanning plus alarm, error-detection procedures, self-activation during hang mode, and self-diagnostics; e.g., additional functions: protocol conversion between internet and industrial online bus [25].

3.METHODOLOGY

The Fig 1. shows the flow diagram of the research work. It includes ACB, LabVIEW, and power control. ACB is a circuit breaker that protects the circuit die from short circuits and under voltage. ACB can operate both manually and automatically. ACB has a shunt, coil closing coil, undervoltage, and coil spring charge motor. The shunt coil is an electromagnet that plays a crucial role in the tripping mechanism of the ACB. The shunt coil is connected to a protective relay or control system that monitors various electrical system parameters, such as current, voltage, or power. When the protective relay detects a fault condition, such as an overcurrent or short circuit, it sends a trip signal to the shunt coil. An under-voltage coil in an Air Circuit Breaker is a component that functions as a protective mechanism. It is designed to trip the circuit breaker when the electrical system's voltage falls below a predefined threshold. This threshold is typically set to a level considered unsafe for properly functioning the connected equipment or the system. A spring charging motor is a mechanism used to charge the closing springs of the circuit breaker. In an air circuit breaker, the closing coil is an electromagnet that closes the breaker's contacts. When the closing coil is energized, it generates a magnetic field that attracts the moving contact toward the fixed contact, effectively closing the circuit. When the control system signals to close the circuit breaker, it energizes the closing coil.

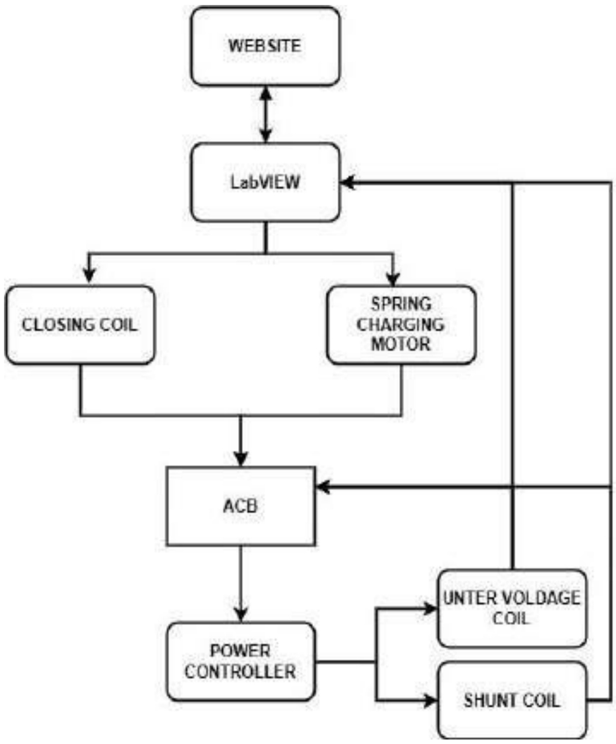

Fig. 1. Flow diagram of Proposed work Flow diagram

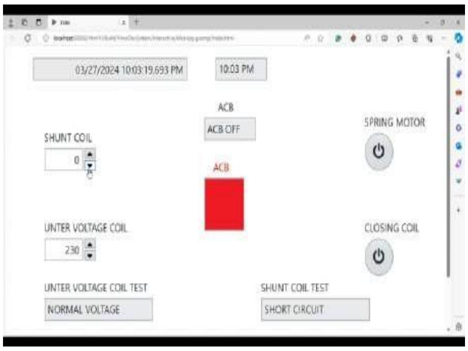

Fig. 2. LabVIEW block diagram program

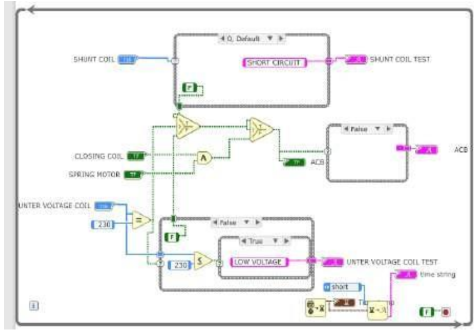

Fig. 3. Short circuit testing

Lab view is an application and development environment for a visual programming language from National Instruments. LabVIEW used instrument control and industrial automation. National Instruments' LabVIEW software is not typically used for traditional web development. However, National Instruments does offer solutions that integrate LabVIEW with web technologies to some extent. For instance, they provide tools like LabVIEW Web UI Builder that enable users to create web-based user interfaces for LabVIEW applications. The power control system controls the power distribution and changes a signal in case of any fault in the circuit. Suppose the power control detects any short circuit or under-voltage circuit. In that case, it is transmitted by an ACB shunt coil or under voltage coil signal. Then, the ACB will be off as soon as the ACB signal is received So it can prevent power loss. The signal from the shunt coil and under voltage coil goes to LabVIEW. Send that signal to the LABVIEW process and then send the hazard warning information from the website. Turn on the ACB, which has been turned off once. The spring charge motor should be charged, and the closing coil should be turned on. It can be controlled from the Website.

The Fig 2. shows the LabVIEW block diagram program. LabVIEW components like control, indicator, node, case structure, loop, times- S tamp, select, equal, less or equal, and AND gate are used. String data type, Boolean data type, and Numeric data type are used in this LabVIEW program. A three-case structure is used, which controls ACB on and off, and the website risk notification shows. It detects when a short circuit and a voltage circuit occurs. The shunt and under- voltage coils are alternately given numeric Boolean instead of ACB. A Boolean switch is an alternative to the spring charge motor and closing.

4.RESULTS AND DISCUSSION

The Fig 3. shows data from the shunt coil instrument as a short circuit. When that data goes to LabVIEW, the ACB turns off the main supply, thereby avoiding a short circuit, and the website will give a warning that there is a Short circuit.

The Fig 4, shows the instrument's high voltage. When a data under-voltage coil comes, the ACB turns off the main supply, so damage to the instrument can `be avoided. The high voltage data comes to LabVIEW, and the website warns that the power is high voltage.

The Fig 5. shows the instrument's low voltage. When a data under-voltage coil comes, the ACB turns off the main supply, preventing damage to the instrument. The low voltage data comes to LabVIEW, and the website warns that the power is low voltage.

The Fig 6 shows shunt coil and under voltage coli come from the data instrument of short circuit and high voltage. When these two data types are received, the ACB turns off the main supply. By this, instrument repair can be avoided. These two data types go to LabVIEW, and the website warns about high voltage and short circuits.

The Fig 7 shows shunt coil and under voltage coli come from the data instrument of short circuit and low voltage. By this, instrument repair can be avoided. These two data types go to LabVIEW, and the website warns about low voltage and short circuits. When these two data types are received, the ACB turns off the main supply.

The Fig 8, shows that ACB is off when there is a short circuit, low voltage, and high voltage danger. There are two ways to turn the ACP back on. One method is to turn on the close button after manually charging the ACB spring coil. Alternatively, suppose the spring coil in the ACB is automatically charged, and the closing coil is turned on automatically. In that case, the ACB will turn on the main super again. They have given the second method in the above picture, and ACB is on state. Short circuits and under voltage can be detected and prevented through this project. It makes it impossible to collect past data by virtue of this short circuit. The exact location of the undervoltage cannot be determined. So it can be detected in the area where a short circuit or under voltage is happening and it can be turned off through this many places will be stuck without power. When applying this in real-time, it needs a control unit. It should be monitored from one source as well.

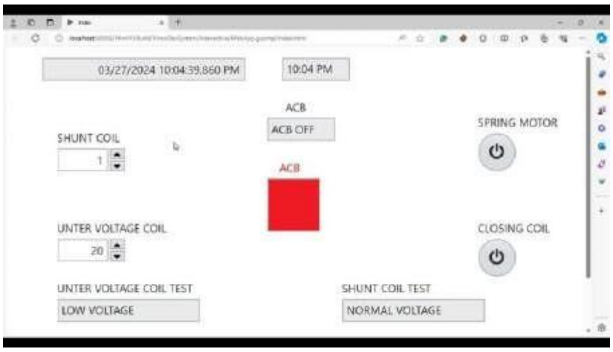

Fig. 4. Hi gh voltage testing

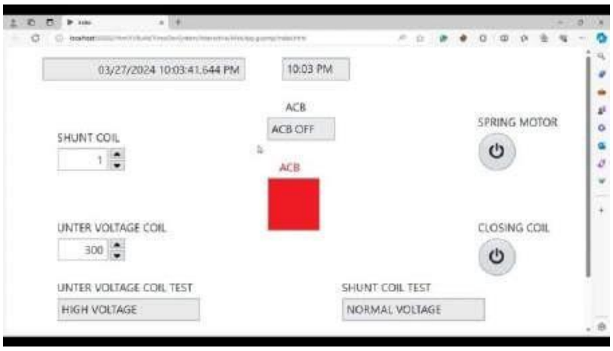

Fig. 5. Low voltage testing

Fig. 6. High voltage and short circuit testing

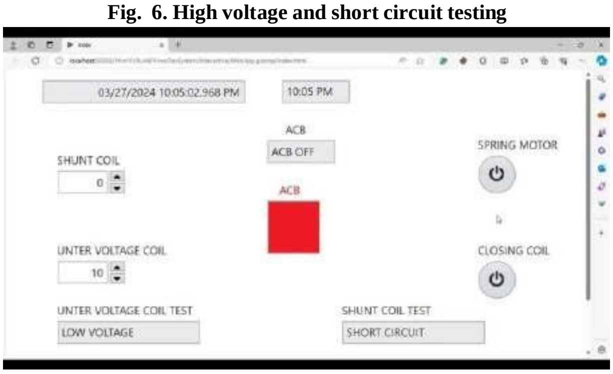

Fig. 7. Low voltage and short circuit testing

Fig. 8. Spring charge motor and closing coil test

5. CONCLUSION

Power distribution systems are being integrated with air circuit breakers (ACBs) to ensure efficient and reliable electricity and monitor short circuits and Undervoltage in real time using LabVIEW. For that reason, this is a positive step forward in providing more effective control over the city's energy supply. This enhanced protection against overloads and short circuits is crucial for areas with high power demands within urban environments as ACBs provide such. Consequently, the ability to monitor this system through LabVIEW has become an important component for predicting failures, hence reducing downtime rates and ensuring higher safety levels at large. Additionally, website interface integration enhances accessibility, allowing remote control or monitoring and facilitating on-time interventions, increasing efficiency during operations. Therefore, it could be argued that this holistic approach makes urban power distribution more dependable and contributes toward optimal energy use in modern cities.

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