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Measurement of operating time of VCB

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Abstract
The "Measurement of Operating Time of VCB" project presents a compact and innovative system for accurately determining the operating time of a Vacuum Circuit Breaker (VCB) by integrating Internet of Things (IoT) technology. The system is designed to capture phase-wise operating time, specifically R, Y, and B phases during three essential operations: closing, tripping, and close-open transitions. It employs the ESP8266 Wi-Fi module to transmit real-time data to the thing speak cloud platform, for visualization of operating time metrics. This IoT-enabled framework ensures precise measurement, timely data logging, and remote accessibility, making it suitable for various sectors, including industrial plants, power transmission systems, substations, and railway electrification networks. Here we provide an effective, scalable, and low-cost solution that supports performance verification, and diagnostic analysis of VCBs. By utilizing a portable hardware setup, the system facilitates on-site testing and real-time evaluation of switching behavior, improving maintenance practices and system reliability. The integration of cloud-based monitoring adds further value by ensuring data availability for historical analysis.

Keywords: Vacuum Circuit Breaker (VCB), Internet of Things (IoT), trip, close, close-open, operating time, substation

1. Introduction

In the current era of rapid technological advancement, the integration of Internet of Things (IoT) technologies is significantly transforming electrical systems monitoring. The ability to remotely collect and analyze system data in real-time has introduced new opportunities for enhancing safety, reliability, and efficiency in power networks. One of the most critical devices in medium-voltage systems is the Vacuum Circuit Breaker (VCB), which isolates faulty sections during abnormal conditions like overloads or short circuits.

A VCB must operate within a specific time range (20-40 milliseconds) which depends on its contact distance to ensure proper coordination with protection relays. If the breaker takes too long to operate, it may cause miscoordination or fail to interrupt a fault in time leading to equipment damage. Thus, measuring and monitoring the VCB's operating time plays a vital role in maintaining a reliable power system.

The operating time of a VCB refers to the duration required for its contacts to close, trip, or close-open cycle. Over time, mechanical wear, distance between contact or internal degradation may lead to increased operating time, impacting the breaker's effectiveness. Accurate measurement helps detect early signs of wear and ensures timely maintenance or replacement.

Additionally, improper operating time can cause relays to misinterpret normal operations as faults, triggering unnecessary tripping. In protection systems, timing precision is essential for proper relay coordination and safe fault clearance. Monitoring these values can improve system planning, reduce downtime, and increase the life expectancy of circuit breakers.

Traditional VCB testing methods often involve expensive or bulky equipment that is not easily deployable in field conditions. Hence, there is a clear need for a portable, easy-to-use, and accurate solution that can capture and store VCB timing data reliably.

2. Literature Survey

The measurement of operating time in Vacuum Circuit Breakers (VCBs) is a critical aspect of evaluating their performance and reliability in modern power systems.

VCBs are widely adopted for medium- and high-voltage applications due to their effective arc-quenching capabilities, minimal maintenance requirements and environmental safety. The operating time, which includes the duration from the trip signal to contact separation (opening time) and contact closure (closing time), is a key parameter affecting fault-clearing efficiency, relay coordination, and overall system stability.

In a study by Hsu *et al.* [1], two primary methodologies for detecting VCB closing time were explored: contact separation measurement (an intrusive technique) and vibration-based detection (a non-intrusive method). While the contact-based method offers accuracy, it presents limitations in continuous monitoring and potential wear on the equipment. In contrast, the vibration-based method provides a non-intrusive, real-time monitoring alternative with minimal system impact, although concerns about data noise and signal interpretation remain.

Weng *et al.* [2] proposed an online measurement method for analyzing mechanical time characteristics of circuit breakers using transient voltage and current signals. However, the method's accuracy is highly dependent on filtering noise from fast, short-lived transients and requires extensive validation using high-bandwidth sensors. Achieving a measurement error under 0.2 ms involved rigorous calibration and system modeling.

Odon *et al.* [3] developed a microcontroller-based circuit breaker timing test system aiming for a low-cost, accurate solution to replace bulky and expensive commercial timing testers. The design emphasized electrical isolation and protection using optical components and transient-suppressing elements. Despite being effective, challenges arose in achieving accurate multi-contact measurement and safeguarding sensitive electronics during high-energy switching operations. Their design achieved a timing resolution of 0.1 ms, making it suitable for practical applications in field testing.

These studies collectively demonstrate the ongoing research efforts aimed at improving the precision, reliability, and practicality of VCB operating time measurement. While contact-based and signal processing methods show promise, there remains a clear need for solutions that are both accurate and easily deployable in field environments. The integration of IoT-based systems is emerging as a viable alternative, offering remote monitoring, real-time analytics, and reduced cost, making them particularly attractive for modern smart grid applications.

A. Role of IoT in power system monitoring

The Internet of Things (IoT) has opened up new possibilities for automation and remote monitoring in power systems. In this project, IoT is used to build a smart and compact device for VCB timing measurement. By using a Wi-Fi-enabled microcontroller (ESP8266), the system records the opening and closing times of each phase (R, Y, B) and uploads the data to the ThingSpeak cloud platform.

Compared to conventional equipment, the IoT-based system is cost-effective, portable, and easy to integrate into existing switchgear systems. It offers a practical solution for substations, industries, and railway networks where real-time monitoring and quick diagnostics are critical.

By enabling continuous observation of VCB performance, IoT technology helps ensure that protection systems respond quickly and correctly during fault conditions, improving the reliability and safety of the overall power network.

3. Methodology

A. Block Diagram

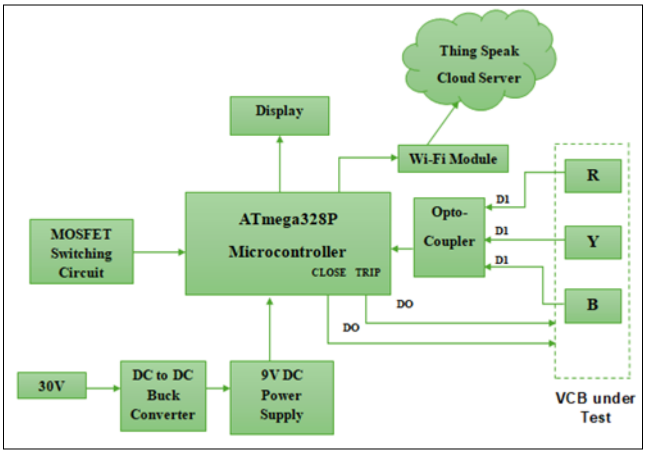

Fig 1: Block diagram of measurement of operating time of VCB

B. Hardware Components

Arduino UNO: It is based on the ATmega328P microcontroller, which provides a balanced combination of performance and simplicity. In this project, Arduino Uno is used to read sensor inputs (e.g., pushbutton), communicate with modules (like Wi-Fi or display), and control outputs (like LEDs) based on programmed logic. It acts as the central controller of the system.

Fig 2: Arduino UNO

The Arduino Uno is powered via USB or an external adapter, offering flexibility in power supply options. A reset button is included for manual or software-triggered resets. Its simplicity and robust community support, along with compatibility with the Arduino Software (IDE) [5].

Wi-Fi Module ESP8266: The Wi-Fi Module ESP8266, a highly integrated and cost-effective Wi-Fi microchip used for enabling wireless connectivity in embedded applications. It allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using commands.

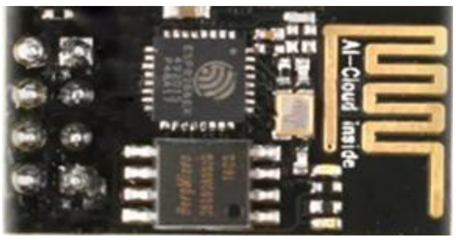

Fig 3: Wi-Fi Module ESP8266

The ESP8266 can be programmed directly using the Arduino IDE. Power can be supplied via 3.3V regulated input, and its compact design allows easy embedding in this device. Despite its small size and low cost, the ESP8266 offers robust capabilities for real-time data monitoring, wireless communication, and remote device control [6].

Optocoupler (PC817): Optocouplers are used to isolate unwanted signals by physically separating high-voltage circuit systems from low-voltage systems. This is used here to transfer electrical signals as an input to microcontrollers and prevent high voltage emitters from affecting lower power circuitry. They can transfer digital (on-off) signals and can act as an electronic switch.

This isolation protects low-voltage control circuits from high-voltage spikes and noise, which can cause damage. By converting electrical signals to light and then back to electrical signals, optocouplers effectively provide a barrier that prevents direct electrical connection, ensuring the safe and reliable operation of sensitive electronics. When the input side's LED is activated by an electrical signal, it emits light, which the photodetector on the output side captures, generating an electrical signal in the isolated output circuit [6].

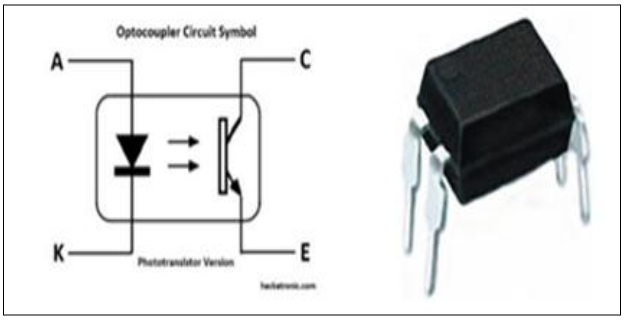

Fig 4: Opto-coupler

P-Channel MOSFET: A P-channel MOSFET uses hole flow as the charge carrier, which has less mobility than the electron flow used in N-channel MOSFETs. In functional terms, the main difference is that P channel MOSFETs require a negative voltage from the gate to the source (VGS) to turn on (as opposed to an N-channel MOSFET, which requires a positive VGS voltage) [6].

This makes P-channel MOSFETs the ideal choice for high-side switches [6].

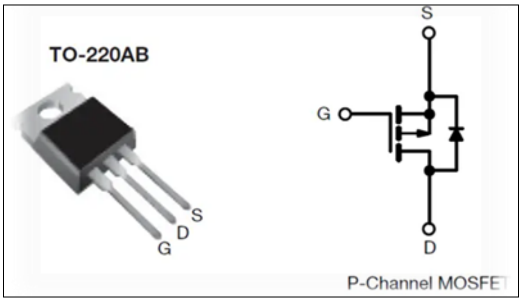

Fig 5: Power MOSFET

LM2596S DC-DC Buck Converter Power Supply: A buck converter or step-down converter is a DC-to-DC converter which decreases voltage, while increasing current, from its input (supply) to its output (load). Used for converting voltage 12 V, down to lower voltage 9V [6].

Fig 6: DC-DC Buck Converter

SPDT Switch: An SPDT (Single Pole Double Throw) switch is a type of electrical switch that allows one input (pole) to connect to one of two outputs (throws). It has three terminals: one common terminal and two output terminals.

When the switch is toggled, the common terminal connects to either of the two outputs, allowing current to flow through one path at a time. Controlling the direction of current flow in a buck converter [6].

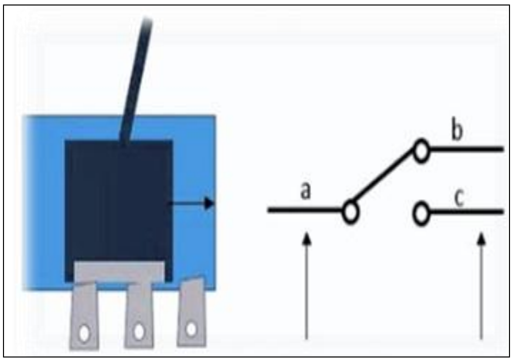

Fig 7: SPDT Switch

LCD Display: 4-terminal LCD display is a type of Liquid Crystal Display module, commonly used for basic alphanumeric or numeric display the typical pins are: 1. VCC-Power supply (usually +5V or +3.3V), 2. GND-Ground connection, 3. SDA (Data Line)-used for sending serial data, 4. SCL (Clock Line)-Carries the clock signal for synchronization. They are used with Arduino microcontrollers to show messages, VCB operating timings, or system status. This is efficient for our compact and scalable project [6].

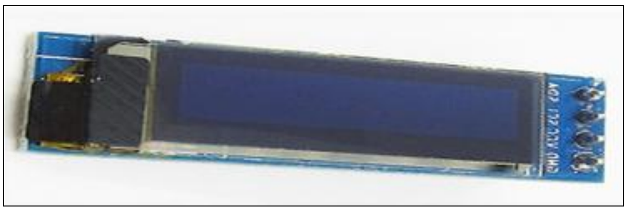

Fig 8: LCD Display

Push Button: A tactile switch is a small, momentary push-button switch designed to provide noticeable physical feedback (a click or tap) when pressed. It is used to control the signal and execute the VCB operation manually [6].

Fig 9: Tactile push button

4. Working

This project measures the operating time of a Vacuum Circuit Breaker (VCB) using R, Y, and B phase signals. The phase signals go through opto-couplers to safely detect when the breaker opens or closes. An ATmega328P microcontroller records the exact time when phase signals disappear or reappear. Based on this, it calculates the time taken to trip or close the VCB. The result is shown on a display and also sent to the ThingSpeak cloud using a Wi-Fi module. A MOSFET switching circuit is used to send TRIP and CLOSE signals to the breaker. Power is supplied using a 30V input converted to 9V DC through a buck converter. This system gives accurate and real-time monitoring of VCB operation time. It then uses the Wi-Fi Module ESP8266 module to upload this data to the ThingSpeak IoT platform. This platform acts as the central hub for monitoring and analysing real-time VCB performance, offering a user-friendly interface for remote access and data visualization.

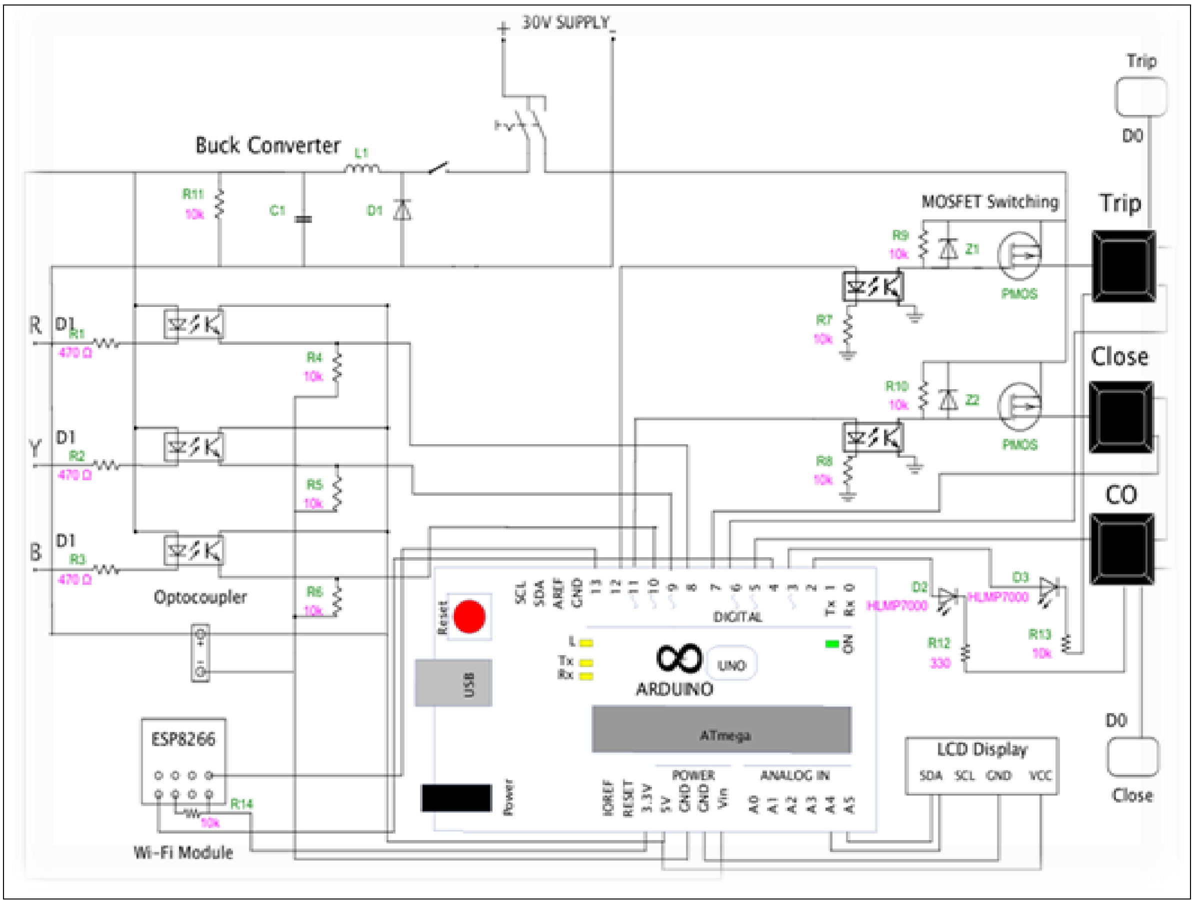

Fig 10: Circuit Diagram

5. Testing & Results

Testing the VCB means making sure it works properly and safely. Here, Test is taken on an 11KV Vacuum Circuit Breaker. Which have 6 to 10 mm distance between fixed and moving pole. Open and close correctly, if the internal parts are in good condition, and if it can stop the flow of electricity during a fault.

These tests help us know that the VCB will protect the system when something goes wrong. Evaluation of measurements obtained using the Scope Circuit Breaker timer.

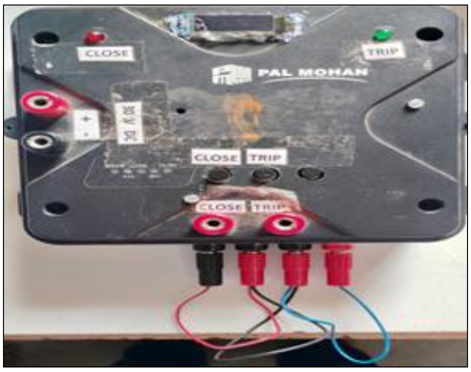

Fig 11: VCB Timing measuring meter

Fig 12: Close & Trip Time (LED Shows Operation)

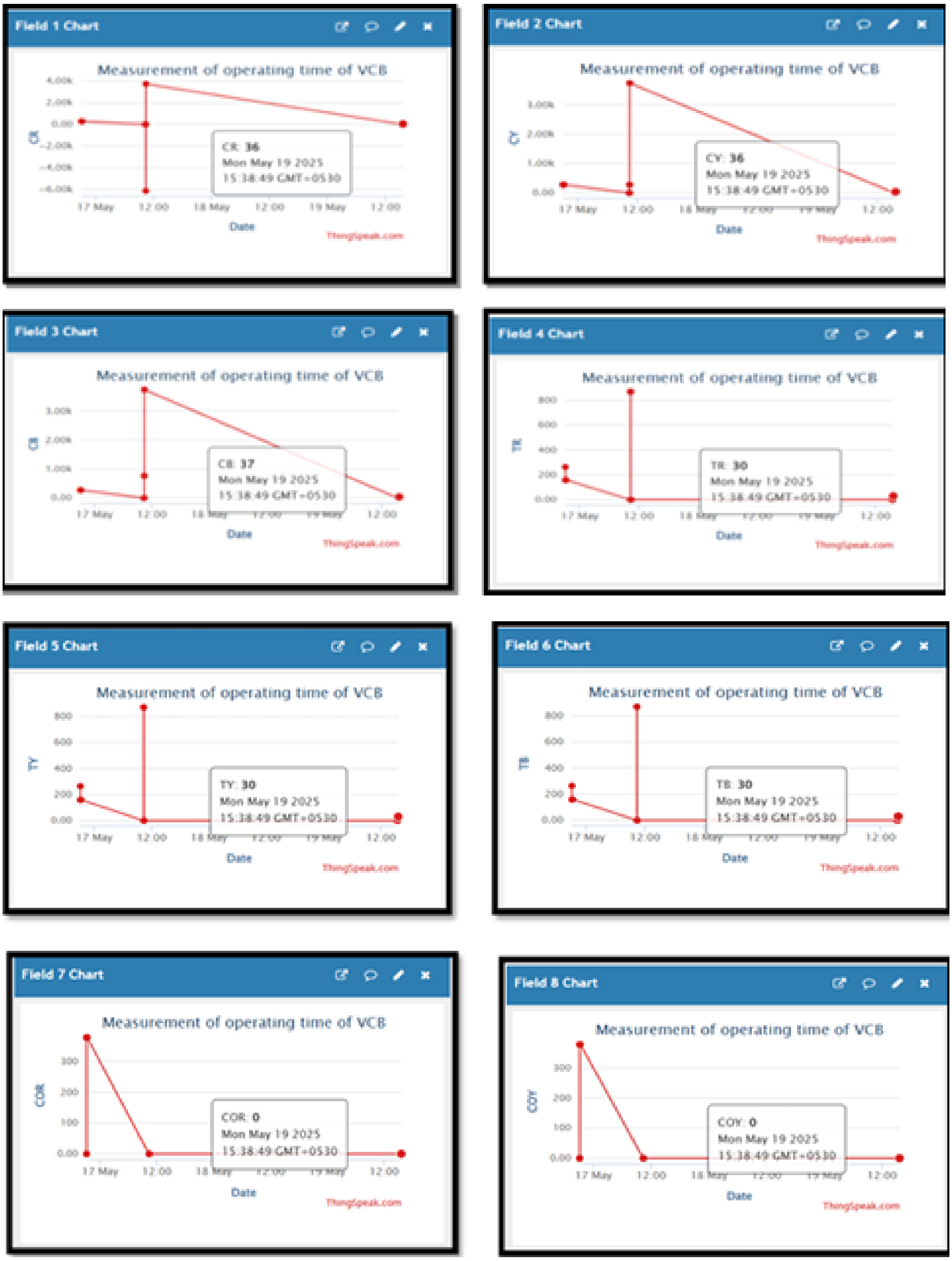

Fig 13: VCB test result of trip, close & close-open on ThingSpeak [4]

6. Future Scope and Conclusion

A. Future Scope

Measurement kit: It helps to measure operating time of VCB which is used in maintained purpose and makes the power system more efficient, reduces unnecessary losses and saves time. In future with integrating artificial intelligence it can easily handle the measuring system and timely give alerts. Major use of this compact size kit will be increased and it helps the mass production of measurement kit. Storing data on budget friendly cloud platforms future versions can integrate with more cloud services and mobile apps to make the system user friendly and cost effective for small scale industries and local substations.

B. Conclusion

This project presents a method to measure the timing of Vacuum Circuit Breakers (VCBs) during close, trip, and close-open operations. By accurately recording these timings, it becomes easier to maintain the breaker in good working condition. If any unexpected differences are seen in the timing, it may be due to uneven distances between the breaker poles. Such issues can cause time delays in tripping, which might lead to faults like earth relay fault operation. Regular checking and maintenance of the VCB can help avoid these problems and ensure the system runs smoothly. Also, saving the timing data to the cloud allows for easy access and better analysis to support future maintenance and improve system reliability.

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