SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V10I8P117

Volume 10 Issue 8, 176-184, August 2023

Original Article

A New Technology to Make Smaller Power Grids Work Better

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Received: 17 June 2023 Revised: 21 July 2023 Accepted: 14 August 2023 Published: 31 August 2023

Abstract - *Controls and remote controls are generally used on more extensive power lines and less commonly on smaller lines. Efforts are being made to automate small power plants. These efforts include grid monitoring, developing autonomous grids, using technologies to forecast and monitor energy demand and implementing these services better requires more intelligent computer systems and equipment. These components work like traditional circuit breakers to protect the electrical system. However, the Smart Breaker stands out by offering multiple functions. It protects you from dangerous electrical surges and can cause power outages if the current is too high. In addition, it can be controlled remotely, allowing individuals to work within the power grid without physically approaching it. Moreover, it has the unique ability to assess energy consumption. These unique features have evolved with future developments, including more intelligent electronic systems. This paper focuses on a unique "smart breaker" device that performs test tasks. This includes power management, anomaly detection, device networking and power consumption analysis.*

Keywords - *Technology, Power, Energy monitoring, Electronic circuits, Control.*

1. Introduction

Technological advances have greatly improved the automation of the main transmission and communication networks for distribution [1]. However, small-scale electricity distribution faces various challenges as it increasingly incorporates energy from renewable sources, such as solar panels and wind turbines [2, 3]. Renewable energy inefficiencies and invisibility can lead to power instability and excessive wiring issues. To overcome these challenges without incurring grid upgrade costs, it is necessary to manage energy consumption and generation effectively [4, 5]. This requires careful monitoring of specific areas of the grid and necessary adjustments in electricity consumption and storage to ensure the stability of energy consumption and storage, in addition to the need to expand new devices capable of creating and controlling the grid [6, 7]. Austria's current iniGrid academic project focuses on developing such devices, one example being the smart breaker [8]. These state-of-the-art devices offer promising solutions to the abovementioned problems by combining power management and network security functions in a single package.

2. Smart Breaker Concept

They are introducing smart breaker, a cutting-edge solution combining circuit protection and remote control capabilities. Its advanced design effectively handles power fluctuations, making it highly suitable for various power applications. Additionally, this intelligent breaker offers the advantage of circuit control [9]. To access this feature, equip the Smart Breaker with a shunt trip and reclosing unit. While some adjustments and maintenance may be required, the numerous benefits of this system are evident [10]. Furthermore, smart breakers go beyond circuit protection by incorporating smart meter functionalities like voltage monitoring and load information. These added features align perfectly with customer's needs in today's grid environment. As a result, smart breakers have emerged as tools for monitoring and improving energy efficiency within an intelligent grid setting [11, 12].

2.1. Technology of Hybrid Switching

Conventional circuit breakers have limitations that make them less suitable for smart grids. One limitation is that it cannot be controlled remotely without additional cost. Another limitation is that their lifetime is limited due to their operating characteristics. A possible solution to the second limitation is to develop hybrid switches. Such a switch combines various components for efficiency. Although the concept of hybrid transformation has been known for a long time, it has only been applied in specific contexts due to various challenges. These challenges include a lack of suitable materials, power loss and overheating problems, difficulties in diagnosing power system problems, inability to reduce switch sizes and high manufacturing costs. Hybrid switching is becoming increasingly crucial in innovative grid technology because materials have made it possible to design more miniature switches that can handle higher power loads while reducing energy consumption. This means they can deliver switches that have been used extensively and yet effectively can be done, even if there is a fault. Additionally, hybrid switching enables remote control and management of security measures.

In a traditional system, the current flows through a specific channel controlled by a switch (SW1), while another component called an IGBT remains passive This system uses the low voltage channel earlier than an IGBT, as indicated by the red line, resulting in better energy efficiency. This can be seen in the bottom graph of Figures 2 and 3. The microcontroller detects and activates the IGBT if there is an electrical abnormality, such as a short circuit. This device opens the switch and transfers the short circuit current to another medium. By controlling this process, the IGBT can turn off the current after a predetermined time. During this time, the switch goes in to fix any problems, and the IGBT quickly reduces the current to zero, thus avoiding problems that can occur when the current fluctuates dramatically when the IGBT is off, which can cause higher voltages to occur. However, this energy is controlled by another device. Any residual energy within the system is ultimately dissipated using the identical mechanism. Upon reaching a voltage level of zero, an additional switch is triggered, resulting in the termination of the electrical connection.

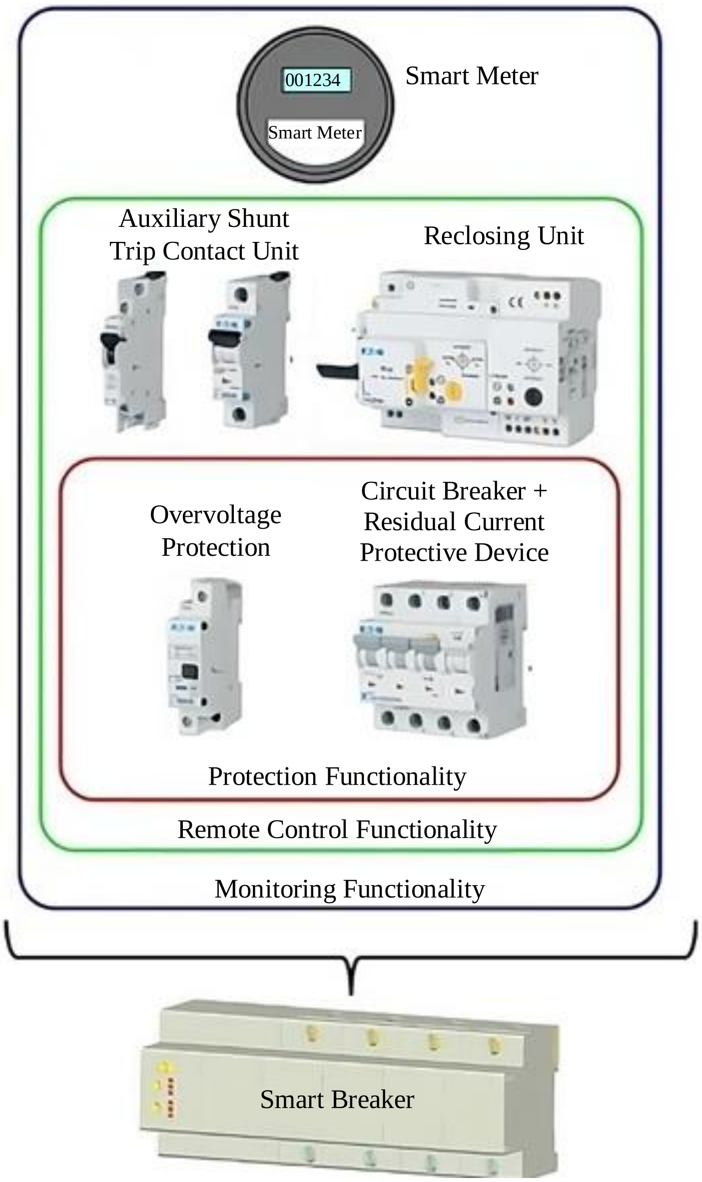

Fig. 1 The smart breaker concept is a device that combines surveillance, remote control, and security features into a single unit

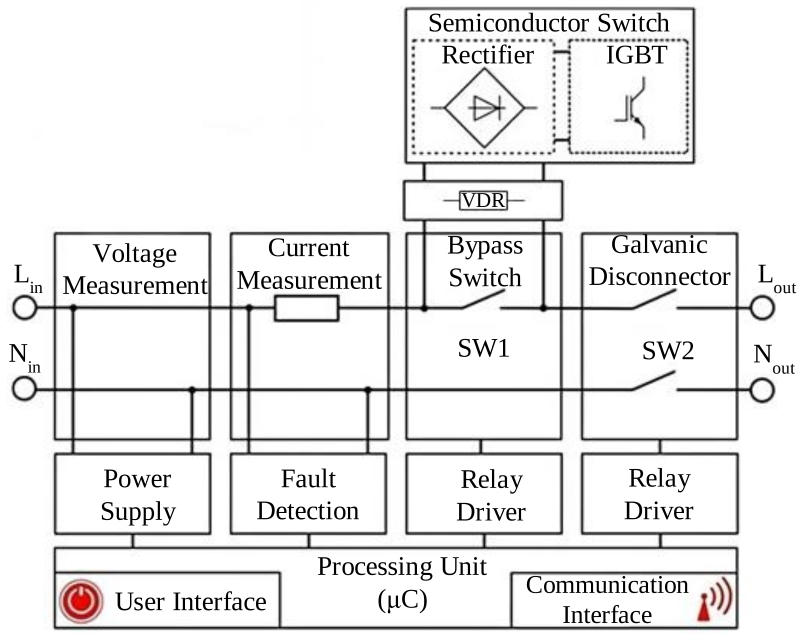

Fig. 2 This is a diagram of the smart breaker. It uses blocks to represent smart breaker components and how they connect

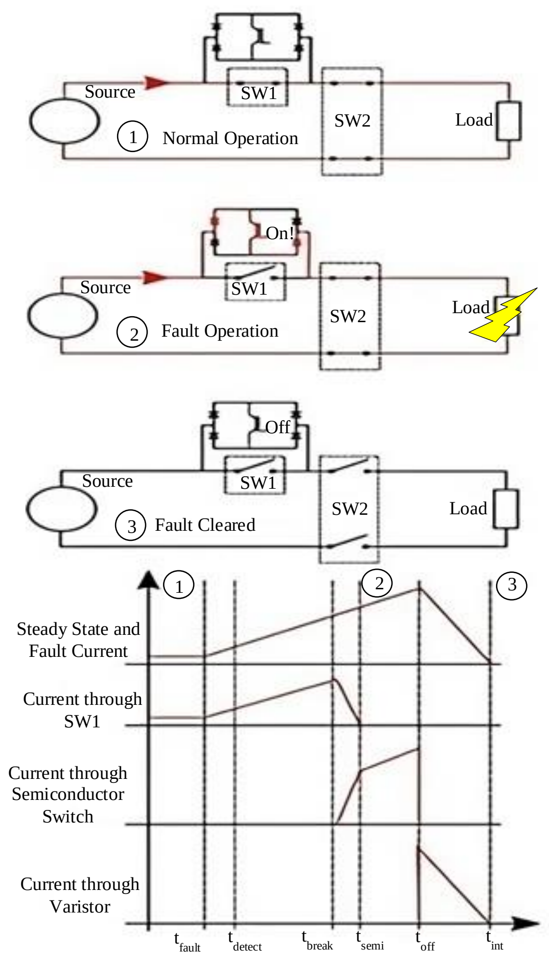

Fig. 3 Suggests what occurs when the smart breaker turns off during a short circuit

Initially, a technical issue arises, often referred to as a bug. During this process, the initialization, detection, and subsequent operation of the smart breaker security device can be detected. The smart breaker uses a particular component called an IGBT to interrupt the current in the event of a fault.

However, it should be noted that an IGBT requires a certain amount of time to eliminate the fault. Once this occurs, the current is zeroed, ensuring the system is isolated and safe. For a particular switch to work correctly, it requires two essential components.

First, it must be able to shut down quickly in case of an error. Second, it must immediately indicate any discrepancies. This is very important as it prevents excessive current from being disconnected from the switch, thereby reducing the chances of damage.

2.2. Hybrid Switching Technology

Unlike traditional circuit breakers, which generate hot air and metal vapour while drawing an arc, smart breakers break the circuit efficiently and quickly without arcing This is done by using semiconductor switching elements to split the current. As a result, the smart breaker operates without the need for a gas outlet.

Figure 4 shows an industrial Miniature Circuit Breaker (MCB) that handles 6kA peak disturbances effectively. In this process, the MCB air inlet is operated at 4000 K. This exposure can cause dangerous arc flashes in the terminals on the line side, causing serious concern. Such arc lights can cause severe damage to switchgear systems and endanger individuals. Fortunately, the new smart breaker uses arc-free switching technology, eliminating the possibility of arc-flash events and related problems.

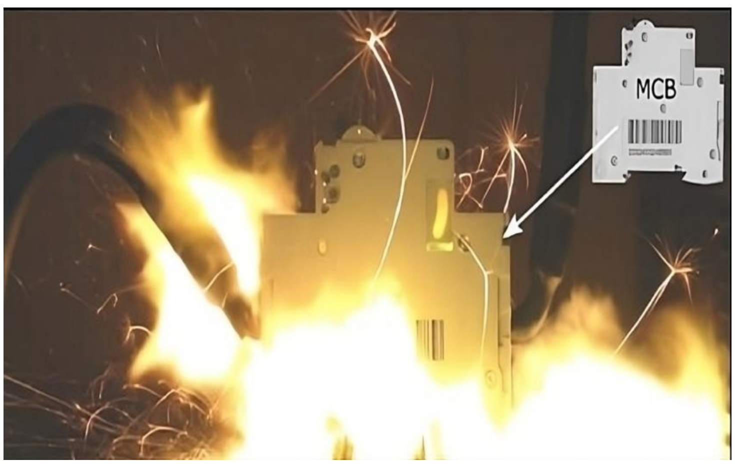

Fig. 4 Shows the air being heated and conducting electricity when the Miniature Circuit Breaker (MCB) interrupts the short circuit

2.3. Fault Detection in Hybrid Switching Systems

Short circuit detection is crucial in hybrid switching systems and requires specific consideration. An essential requirement is a limited amount of time to explore. In order to ensure that the temperature of the Insulated Gate Bipolar Transistors (IGBTs) remains within safe limits, the detection time must be less than 100 microseconds in case of critical faults [13, 14]. The decision to turn off the system component smart breaker must be made now. A complex processing mechanism is generally required to enable faster fault detection procedures [15]. However, a cheap and simple microcontroller can be used instead for a cost-effective solution. As a result, the fault detection algorithm is divided into two parts: one that deals with fast signal processing in hardware and one that performs simple but fast computations in software [16]. This combination provides a fault detection time of less than 60 microseconds capability. Another essential feature that a smart breaker must address is its ability to distinguish between regular and troublesome events, such as motor starts or sudden changes in power consumption. This is necessary to prevent unnecessary decommissioning of the smart breaker. Smart breaker uses a unique approach to identify issues by analyzing power consumption patterns over time to achieve this.

When the observed values deviate from the expected range, it indicates a problem and initiates closure. However, if power consumption remains within the normal range, the smart breaker may operate as intended [16].

2.4. Communication Policy

Extending the remote control capabilities of the device requires communication with other devices. The Smart Breaker uses an advanced wireless network protocol that operates on a fixed frequency. This protocol enables the wireless communication device to be connected to a remote data concentrator [17, 18]. Wireless connectivity is preferred over wired connectivity due to eliminating additional cables simplifying the system. Although wireless connectivity is limited, this is not a concern because it is intended to be used in a limited area, such as a switchboard or cabinet. The switchboard is outside the cabinet for wireless connectivity.

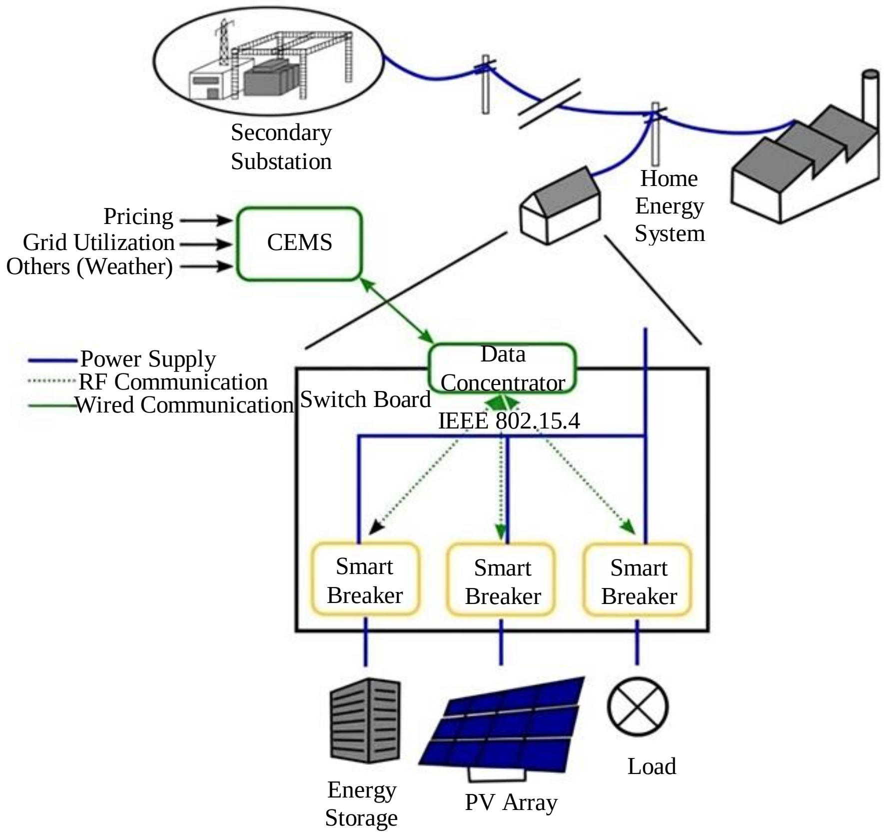

Fig. 5 Communication system

Figure 5 shows the impressive capability of the data concentrator to communicate with multiple master stations through various communication channels, including RS232, RS485, RS422, Ethernet, etc. It also shows compatibility with various protocols, such as Modbus PROFIBUS IEC 60870-5-104, along with other applications and software. A unique Smart Grid scheme will be introduced shortly for easy integration. The system will include Smart Breakers devices that send and transmit power usage data to a central location. This information can predict the extent and direction of energy consumption, enabling utility managers to make and monitor energy efficiency decisions to increase the operation of appliances or generators [19] to ensure adequate power delivery. CEMS is a unique system that can be used in various situations. It can also help identify lost power sources and prevent theft. Furthermore, it can help diagnose electrical issues and ensure proper operation [20].

3. Implementation and Foresight

A smart breaker is a device designed to control surges safely. It can handle up to 125 amps of the electrical system and efficiently handle short circuits and other dangerous electrical issues. This device is designed to work with positive and negative electrodes and is available in various versions [21], some of which offer additional testing capabilities.

3.1. Experimental Design

As shown in Figure 6, the experimental design was considered the most suitable design for overload and short-circuit tests. Specific adjustments were made to ensure a uniform and constant voltage of 240V in the generator system in the 19th century. Adjustable resistors and radiation limiters played an essential role in controlling the rapid flow of hazardous water. A switch system was installed to deal with unexpected events properly. The electrical shut-off was carefully operated to ensure the proper flow of electricity to the circuit breaker, and the experiment was started with caution and patience.

3.2. Current Boundary Line

The experiment illustrated in Figure 7 shows sophisticated fast circuit breaker tests performed on three circuit breakers: Molded Case Circuit Breakers (MCCB), Miniature Circuit Breakers (MCB), And the latest smart switches. MCCB is red, MCB is blue, and smart breaker is green. These colours symbolize their respective breakdowns. Also, the prominent black lines show the high-speed current flowing at the current time, which shows how many synchronous events can occur in a circuit when the breaker uses a strong conductor with impedance equally used. This shows that the time difference between zero and t = 2 ms correctly assumes an entirely different analysis [22, 12].

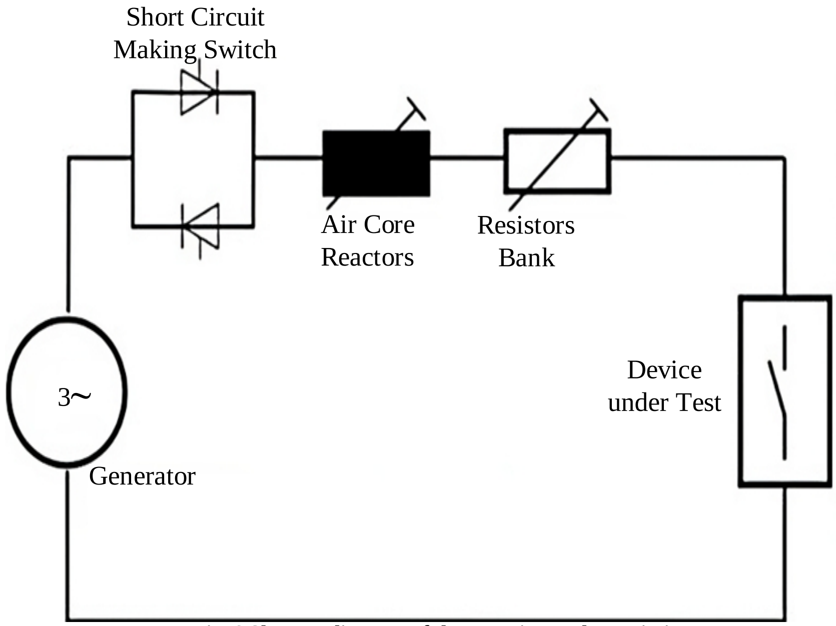

Fig. 6 Shows a diagram of the experimental association

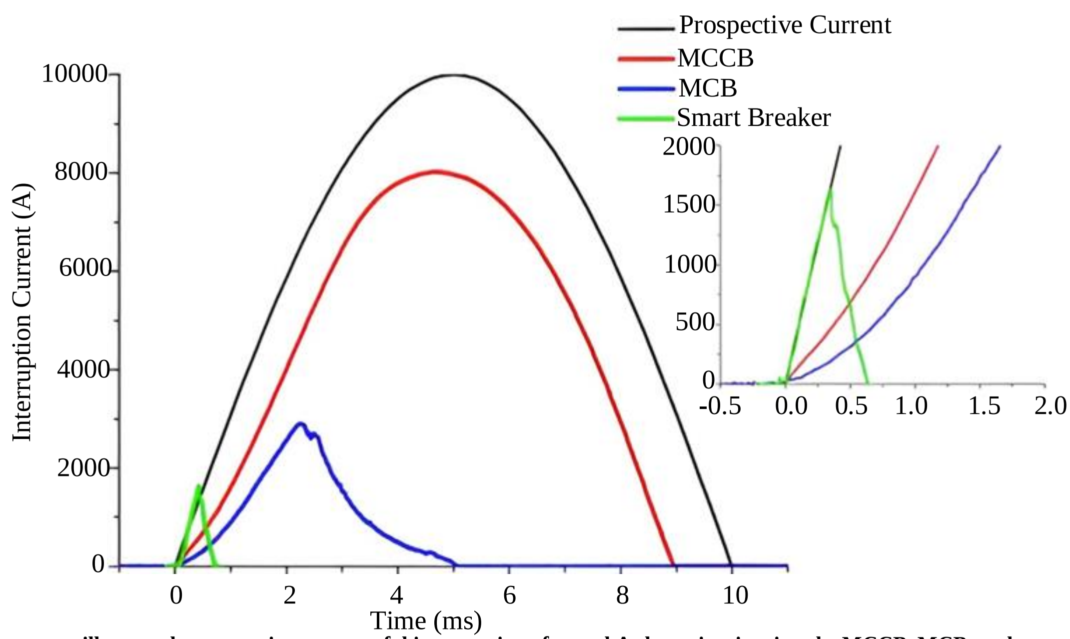

Fig. 7 Shows an oscillogram demonstrating a successful interruption of a ten kA short circuit using the MCCB, MCB, and smart breaker

The occurrence of a short circuit results in the onset of current flow at t = 0. The current potential exhibits a sinusoidal pattern. The cutoff power is zero after a half-cycle of fifty Hz (10 ms). Due to the power limitation of the circuit breaker, the maximum permissible and current peak when the faulty circuit (tint) is significantly exceeded, with tint at 10 ms and Ipeak at kA. This exceeds the analyzed power over short-circuit current time [23]. Figure 7 in Table 1 represents the extraordinary ability of the smart breaker to prevent collisions after a short period. This is due to the smart breaker's remarkable fault detection and high speed enabling circuit switch-off [24]. As a result, after a certain amount of time (usually 1-2 milliseconds), the connection is terminated, and the current information is fixed. The MCCB and MCB attempt to overcome this problem by introducing a series impedance similar to an "arch chute". However, dealing with or pushing back against this pressure can be difficult.

In such cases, the high-speed lines are manually extinguished when it is clear that the arc is out. Table 1 shows smart breaker's impressive performance in debugging by providing let-through power expressed by load support, measured in terms of Joule integral (I2t). Unlike MCCB or

MCB, Smart breaker exhibits low I2t values impressively revealed, 512 times and 19 times below the critical level. This indicates a fault in the load or power supply [25].

Table 1. This determines the duration of the problem and the amount of current flowing through the circuit breakers

Breaker Type	MCCB	MCB	Smart Breaker
I2t (kA2s)	276,7	10,4	0,5
t_{int} (ms)	8,95	5,06	0,64

3.3. Contact Wear-Out

A typical circuit breaker is triggered primarily by arcing [26]. However, installing a smart breaker with an advanced-generation hybrid significantly reduces contact wear and improves switching efficiency even when dealing with high-speed circuits under fault conditions. Figure 8 by eye shows conditions opposite to contacts in conventional MCCBs and smart breakers. The contacts in a typical circuit breaker are designed to withstand a three-sample short circuit break of 10 kA, followed by a bulk (silver-tungsten) tip and a copper touch ho under the contact-sized arm.

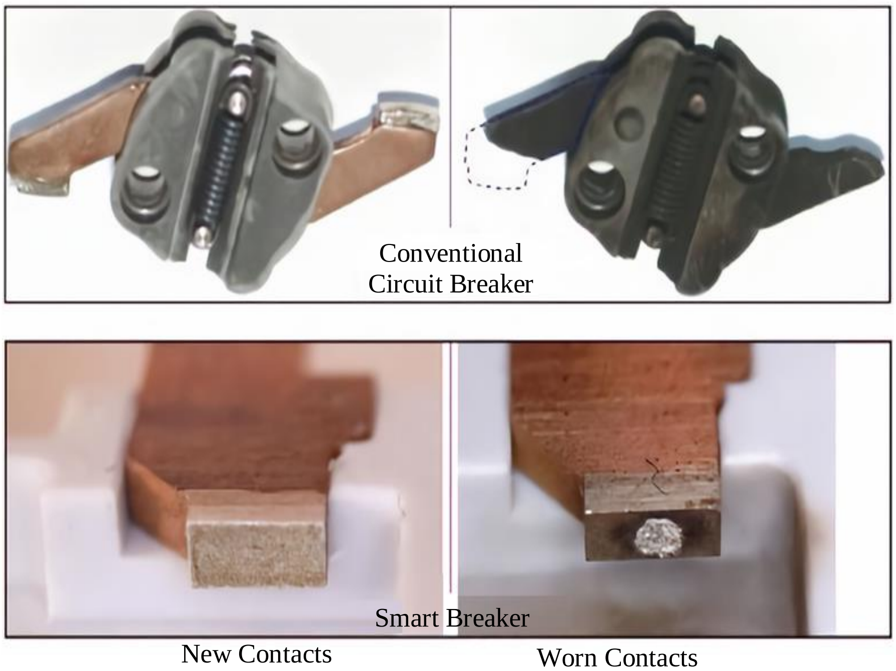

Fig. 8 The left side shows the initial stages of MCCB and smart breaker, and the right side shows their degraded state

4. Conclusion

The iniGrid project involves the development of a device called smart breaker. This innovative device aims to address challenges associated with monitoring and measuring electricity consumption in areas and detect instances of stolen or interrupted electricity.

Moreover, the smart breaker is designed to manage electricity transmission to troubleshoot issues and enhance the efficiency of the power grid. Initial findings from laboratory and real-world tests assessing the effectiveness of this technology within the research project, indicate that the smart breaker surpasses conventional circuit breakers in effectively handling high electrical loads without causing any damage or cable-related problems.

Acknowledgments

We want to acknowledge the valuable input and continued support of our colleagues in the research team, which enhanced the depth and quality of our research.

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