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DYNAMIC CONTACT RESISTANCE MEASUREMENT RESISTANCE FOR CIRCUIT BREAKERS

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ABSTRACT
Dynamic Contact Resistance Measurement (DCRM) is a vital diagnostic technique for assessing the health of Extra High Voltage (EHV) circuit breakers by capturing resistance variations during contact movement. This paper presents an AI-based framework that automates DCRM analysis to accurately detect abnormalities in arcing contacts, main contacts, and operating mechanisms. The system uses machine-learning models to interpret resistance signatures, classify fault patterns, and predict emerging failures before they lead to outages. By integrating historical data, real-time measurements, and intelligent pattern recognition, the proposed approach enhances reliability, reduces maintenance downtime, and enables condition-based monitoring of circuit breakers.

I.INTRODUCTION
Circuit breakers play a vital role in high-voltage transmission and distribution networks, functioning as automatic switching devices that safeguard equipment against overcurrents, short circuits, and system faults. Their operation must be rapid, accurate, and dependable to isolate faulty sections and ensure system stability. Depending on the arc-quenching medium, breakers may be SF_6, vacuum, or air-blast types, with SF_6 and vacuum circuit breakers being predominant in modern AIS and GIS installations due to their compact design and strong dielectric performance. A typical high-voltage breaker contains main contacts, arcing contacts, an operating mechanism, and auxiliary control components, all of which are susceptible to deterioration caused by frequent operations, contact wear, misalignment, and mechanical ageing.

Traditional diagnostic tests such as timing analysis, static contact resistance, insulation measurements, and motor current profiling provide only partial information about internal mechanical conditions. Static measurements capture contact health only in the closed state, overlooking intermittent issues that occur during movement. To overcome these limitations, Dynamic Contact Resistance Measurement (DCRM) has emerged as a highly effective diagnostic technique. DCRM records resistance variations at millisecond resolution during breaker Close–Open or Open–Close operations, producing resistance signatures that reflect contact travel, interface conditions, and arcing contact integrity. Deviations from baseline signatures can reveal contact erosion, increased friction, sluggish travel, misalignment, or abnormal bounce.

This paper presents field-recorded DCRM signatures from 145 kV and 245 kV SF_6 circuit breakers, analyzing their correlation with mechanical behaviour and contact conditions. To enhance diagnostic accuracy, an AI-based methodology is integrated into the DCRM framework. Machine-learning models process resistance waveforms to extract features such as rise patterns, slope changes, event durations, and anomaly points. These features are fed into supervised classifiers and clustering algorithms to automatically categorize fault types, detect deviations from healthy signatures, and predict emerging failures. By combining real-world measurements with intelligent pattern recognition, the proposed AI-enabled DCRM approach strengthens predictive maintenance, minimizes forced outages, and supports life-cycle asset management for critical power system infrastructure.

II.DCRM WORKING PRINCIPLE
The Dynamic Contact Resistance Measurement (DCRM) test operates by injecting a constant DC current, typically around 100 A, through the circuit breaker contacts while the breaker performs its Close and Open operations. During this process, the voltage drop across the contacts is captured continuously using a high-speed data acquisition system operating at 10 kHz or higher. By dividing the measured voltage by the injected current, a resistance-versus-time curve is generated using the relation $R = V/I$.

To complement the resistance measurement, a travel transducer is employed to record the mechanical movement of the circuit breaker. This allows simultaneous observation of contact resistance and travel characteristics, providing a deeper understanding of both electrical and mechanical behaviour during dynamic operation. The synchronized data from both sensors improves diagnostic precision.

The resulting DCRM signature—represented as a time-resistance graph—reveals critical information about breaker performance. It clearly indicates the exact moments when contacts touch or separate, shows the transition between the main and arcing contacts, and highlights any irregularities in the mechanical stroke. These insights help identify contact wear, misalignment, sluggish movement, or other mechanical issues that may affect the reliability of the breaker.

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III.CONNECTION DIAGRAM DESCRIPTION

The block diagram of the system is shown in fig.1.

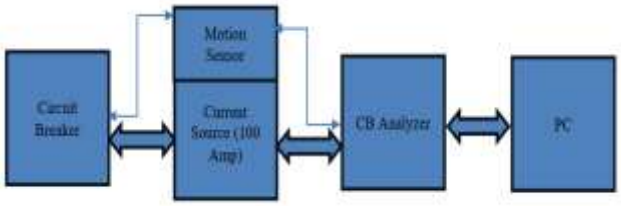


Fig.1.Block Diagram

Test Setup

Step1:TestSetup

The circuit breaker must first be completely isolated. The DCRM test equipment, including the CB analyzer and the constant current source, is then connected across the breaker's main terminals. A motion or travel sensor is mounted on the moving mechanism to capture mechanical displacement. Finally, the DC source and shunt are connected to facilitate accurate measurement of current and voltage during the test.

Step2:BreakerOperation

The breaker is operated through its Close/Open cycle. During this sequence, the DCRM system continuously records the voltage drop across the contacts and the current flowing through the breaker, capturing the dynamic behaviour of the contacts.

Step3:ResistanceCalculation

Using Ohm's Law (R = V/I), the system computes the contact resistance at every instant of operation. The results are then plotted as resistance versus time, travel, or contact position, providing detailed insights into the breaker's electrical and mechanical condition.

IV.RESULTS

The DCRM waveforms wereb analysed and shown in the following figures:

1.Normal DCRM

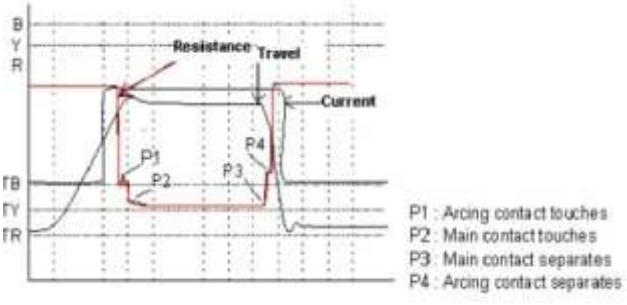


Fig.2.Normal DCRM

When the circuit breaker is in the open position, the dynamic resistance remains high, represented by a horizontal red line. Once the close command is issued, the main contacts engage first, causing the resistance to drop to point P1. As the arcing contacts continue to close, the resistance transitions from P1 to P2, and then stabilizes from P2 to P3 when the breaker is fully closed. During this process, current initially remains zero but begins to rise at P1 and reaches its maximum value at P2, staying constant until P3. When an open command is given at P3, the main contacts separate and resistance rises toward P4, after which the arcing contacts open completely, making resistance reach its peak and current return to zero.

The Circuit breaker health summary is given in the following table based on the above normal health Circuit breeaker

TABLE-I-DCRM HEALTH SUMMARY

Component	Condition	Remarks
Arcing Contact	Good	Smooth slope, gradual resistance drop
Main Contact	Good	Sharp drop, flat low-resistance region
Mechanism	Slight bounce seen	Not alarming; watch in future tests
Resistance Value	Acceptable	~50–70 mΩ flat zone, within healthy range

2.Abnormal DCRM

The abnormal DCRM of circuit breaker is shown in the following fig.2.

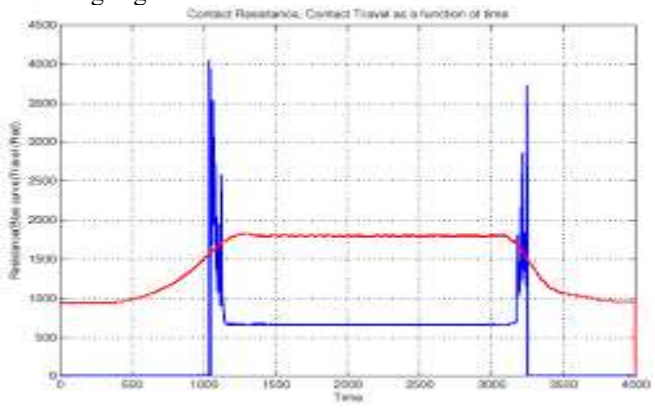


Fig.2.Abnormal DCRM

The DCRM observation shows a sudden change in resistance (around 50–1800 mΩ) followed by a noticeable spike approximately 120 ms after the main contacts touch, suggesting contact bounce. This abnormal spike may indicate issues such as loose or contaminated main contacts, mechanical misalignment, or surface deterioration. It is recommended to inspect the arcing contacts for erosion or misalignment, clean and tighten the main contacts to reduce bounce, and examine the operating mechanism for sluggish movement, worn linkages, or spring fatigue. After completing the necessary maintenance, the DCRM test should be repeated to verify improvements and compare the new signatures with the earlier ones.

V.CONCLUSION

Dynamic Contact Resistance Measurement (DCRM) signatures provide a powerful means to detect emerging faults in circuit breaker contacts by analyzing resistance behaviour over time. Gradual rises in resistance indicate contact wear due to erosion, while sudden spikes or drops reveal possible misalignment during contact engagement. Contaminated surfaces, such as those affected by oxidation or deposits, produce unstable resistance even in regions that should remain steady. In more critical

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conditions, welded contacts are identified when no resistance separation occurs after an open command, showing that the contacts remain stuck. These insights make DCRM a highly sensitive, non-invasive technique that uncovers faults missed by conventional timing tests, prevents major failures, and supports timely maintenance to extend circuit breaker life.

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