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Comprehensive Testing of Air Circuit Breaker Components for Enhanced Functionality

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A B S T R A C T

The Air Circuit Breaker (ACB) is a protective device for electrical circuits up to 50kV and 800A to 10KA. It is designed to interrupt low voltage and safeguard expensive electrical components from short circuits and overcurrent. The ACB comprises mechanical and electrical components. The mechanical components include an arc chamber and a switch for opening and closing. In contrast, the electrical components consist of a shunt coil, closing coil, spring charge motor, and UVR coil. These components are crucial for the operation of electrical circuits. Their proper functioning is essential; otherwise, all components could be damaged. The proposed work introduces an ACB testing instrument that can verify the correct operation of these components. The instrument performs high voltage, mechanical function, and electrical tests to ensure the ACB's functionality.

Keywords: Air circuit breaker, MLFB, UVR coil, shunt coil, ACB Testing instrument

1. Introduction

Air Circuit Breakers (ACBs) are crucial in electrical power systems, protecting against overloads and short circuits [1]. They use magnetic and thermal tripping mechanisms to detect short circuits, promptly interrupting the circuit to prevent further damage [2]. ACBs also safeguard against overload currents [3]. LabVIEW, a system-design platform from National Instruments, is used for visual programming [4]. Industrial PCs (IPCs) are designed to endure harsh conditions and offer reliable performance for critical industrial processes [3]. They can be integrated into larger automation systems and communicate with devices like Programmable Logic Controllers (PLCs), which automate processes in industrial control systems [6][7]. The DMR-8050E-0200 is a handheld barcode scanner for industrial applications [8]. Monitors display visual output from computers [9]. Like the ZD6A143-30GL02EZ, zebra printers cater to various printing applications [10]. Kikusui Electronics Corporation designs and manufactures electronic test and measurement instruments [11][13]. The TOS9320 Scanner and Chroma 61602 are used for testing or measurement applications [12][14]. Servos are closed-loop control systems used for precise motion control [15].

2. Review of Literature

M. SEN et al. ACBs are crucial protective devices in low-voltage power systems to carry current under normal conditions and isolate the circuit during faults [3]. ACBs ensure electrical safety and system reliability by effectively managing electrical power overflow [15]. B. Rane The process of assessment and improvement of the reliability of ACB is explored, and the root causes of failures are eliminated based on various relevant tools [1]. These problems can result in malfunctions like overheating coils, oxidized contact surfaces, inconsistent stator and rotor causing friction, and failures in the tripping device due to power quality issues or manufacturing defects. To address these manufacturing-related faults [16]. Tests on the operating mechanism, including insulation and contact resistance tests, must be conducted to ensure all components function accurately [17].

LabVIEW is not just a coding language but a comprehensive development environment where users can create virtual instruments (VIs) by dragging and connecting functional blocks in a data flow architecture [18]. LabVIEW integrates seamlessly with a wide variety of hardware and software platforms. It includes drivers for standard instruments and devices, enabling users to interface with other programming languages like C and Python [19]. The LabVIEW Robotics Module provides hardware and software development tools for designing robotic control systems. It is an add-on module that enhances LabVIEW's capabilities for robotics applications, offering detailed documentation, example code, and user community support [20]. Hairulazwan Hashim LabVIEW, combined with NI CompactRIO and LabVIEW Real-Time and LabVIEW FPGA modules, automates mechanical endurance tests for circuit breakers. The system consists of multiple independent test stations controlled and monitored by LabVIEW [21].

Air circuit breakers (ACBs) provide overcurrent and short-circuit protection in electric circuits. Short circuit testing is essential to ensure that the ACB can effectively interrupt the circuit in the event of a short circuit. Regular maintenance and testing are vital to prevent failures that can lead to serious consequences [22]. Short circuit testing is a critical part of air circuit breaker maintenance. It involves testing the overcurrent protection features of the circuit breaker to ensure it trips within the specified time under overload and short circuit conditions. This testing helps verify the proper functioning of the ACB in protecting circuits from short circuits and overloads. Short-time and Instantaneous Protection Trips are key aspects of testing air circuit breakers. These tests are essential to verify that the ACB can trip within specified timeframes under different fault conditions, including short circuits. Calibration of the trip unit is crucial to ensure it operates within the required parameters for effective protection [23]. LabVIEW interfaces sensors in a substation, enabling continuous monitoring and control of circuit breakers. The system records data at different intervals, allowing fault detection and appropriate responses such as shedding loads or limiting generation based on specified ranges [24].

3. Methodology

Every Air Circuit Breaker (ACB) has a unique identifier known as the MLFB ID. This ID is scanned using a scanner, and the scanned data is sent to a Programmable Logic Controller (PLC). The PLC then forwards this data to an Industrial PC (IPC), which decodes the MLFB ID. Upon decoding the MLFB ID, we can identify the specific components of the ACB. The testing process for the ACB involves several steps: ID Test or Resistance Test: This test measures whether the ACB-specific coils, such as the shunt coil, under-voltage coil, and closing coil, are functioning correctly. If the ID test is passed, the process moves to the next step. If the test is failed, the printer prints a report.

High-Voltage Test: This test is conducted to find any manufactured terminal contact or short circuits when high voltage is applied to the ACB. The test is performed under two conditions: when the ACB is open and when it is closed. If no short circuit is detected, the ACB passes the test and moves to the next step. If the ACB fails this test, the printer prints a report stating that the ACB failed the high-voltage test. Mechanical Test: The ACB is manually turned on and off in this test. The first step is to charge the spring coil with a servo motor. A cylinder automatically pushes the closed and open buttons if the spring coil is charged. If the coil gets closed and opened in this test, it passes. If not, it fails the test, and the printer prints a report stating that the ACB failed the mechanical test. Electrical Test: The first step in this test is to supply power to the spring coil. After charging the spring coil, a signal is sent to the closing coil to check if it gets closed. Then, a signal is given to the shunt coil to check if the closed ACB circuit is functioning. If the ACB

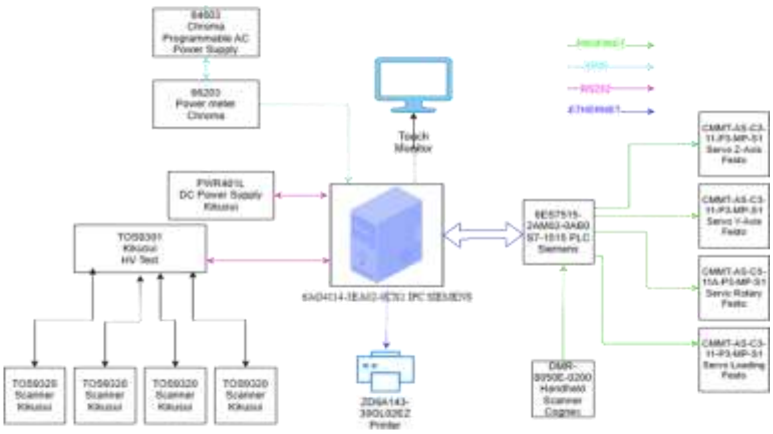

Fig. 1 - Block diagram of the proposed system

passes this test, the printer prints a report stating that all tests are completed. If the ACB fails the test, the printer prints a report stating that the ACB failed the electrical test. If all tests are successfully passed, the ACB is ready for use.

4. Result and Discussion

4.1 MLFB CODE

The Fig 2. It shows MLFB CODE decode. MLFB CODE has 16 characters. These characters are needed to find the variables. For example, the first two characters (1,2) determine whether it is a circuit breaker. For example, the third character defines the breaker line:1st line or 2nd line, or maybe J or T. The fourth character defines a market or functionality-level accessory, such as the IEC09472 circuit breaker. The fifth character defines frame size, for example, 1:FS1 or 2: FS2.The sixth and seventh characters measure rated current. For example, the character has 0, which means 800A, and the seventh character has five, meaning 2500A. The ninth and tenth characters define the EDU type: circuit breaker, Ac non-automatic, EDU350WJ, and EDU360WJ. The 11th characters are defined as poler and n control positions, for example, 3P or 3PN left side. The 12th character defines connection technology as vertical (VV) or horizontal (HH). The 13th character defines the spring charge motor. For Example, S2 means a 24 to 30-voltage DC spring charger motor. The 15th character defines the closing coil. For example, it is 1, which means 24 to 30 VDC. The last 16th character defines the shunt coil. For example, it is 5 means 110 AC shunt coil.

The Fig 3. Shows MLFB CODE decoding sample. Decoded along with the MLFB ID of the ACB and the number of devices installed inside that ACB can be found. Based on this, a selective selection can be made, with "h" meaning 24 to 30 VDC. The last 16th character defines the shunt coil. For example, it is 5 means 110 AC shunt coil.

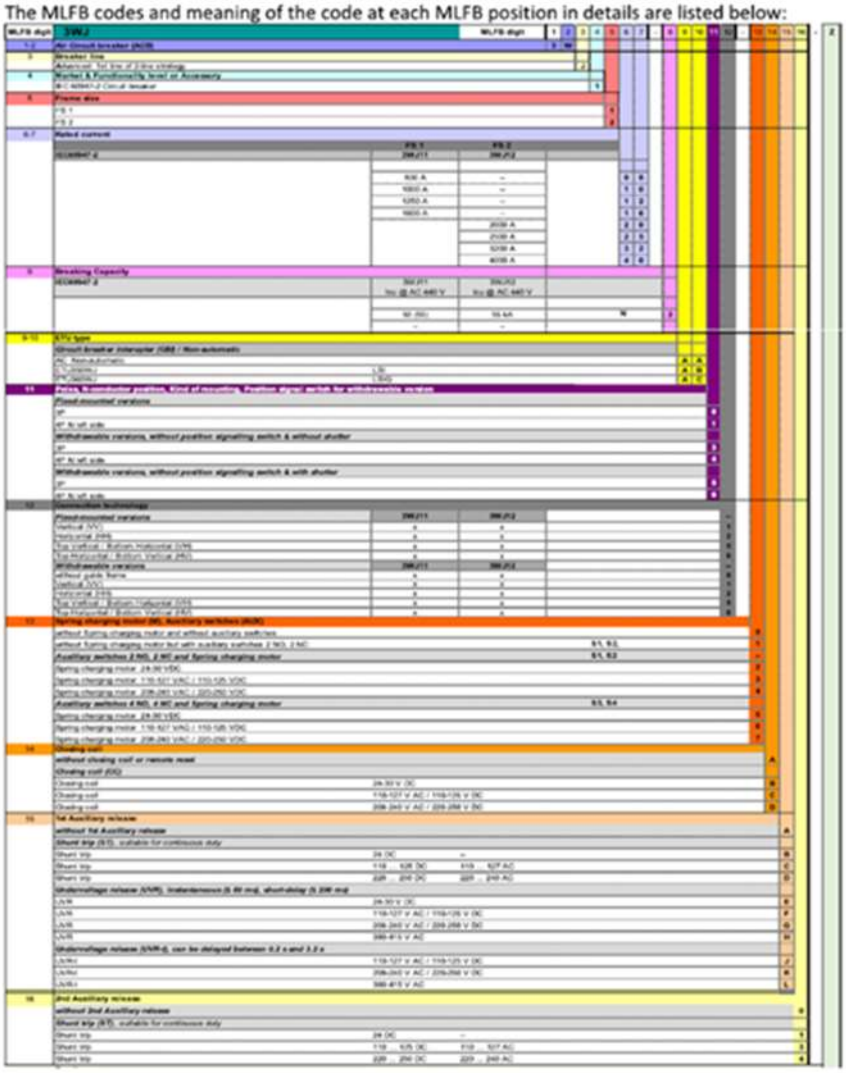
The MLFB codes and meaning of the code at each MLFB position in details are listed below:

Fig. 2 - MLFB Code

4.2 ID TEST

The ID test is used to measure ACB coil resistance, and it works by decoding MLFB CODE; we can measure coil resistance, for example, spring voltage 20.8, current 0.036 spring motor coil applying 20v, and measure spring coil resistance. The resistance value is correct. The coil is in good condition. Otherwise, a defective coil will be manufactured. UVR coil applies 220v. The resistance value 1 is correct, works properly, or is incorrect, which means it is a manufacturing defect. On applying the shunt coil with parameter voltage, the 220V resistance value is correct; it is in good condition. If not, it is a manufacturing defect. All of the coils have to perform well to pass the test. If any of the coils fail, the test will fail.

INDEX	SCAN CODE	3WJ12202AA5240K4
1	3	ID
2	W	
3	J	
4	1	
5	2	Frame Size=2
6&7	2&0	Rated Current=Frame Size-2-2000A
8	2	Breaking Capacity=55KA
9&10	A&A	ETU Type-AC Non Automatic
11	5	Withdrawable Version,without signalling Switch and with Shutter=3P
12	2	Connection Technology=
13	4	Spring Charging Motor & AUX=208-240 VAC/ 220-250 VDC
14	0	Closing Coil=
15	K	1st AUX Release=UVR-1 208-240 VAC/ 220-250 VDC
16	4	2nd AUX Release=Shunt Trip-220-250 DC & 220-240 AC

Fig. 3 MLFB Decode

Main | Process | Process 2

ID TEST DETAILS

TEST NAME	TEST PARAMETER	TEST STATUS	TEST RESULT	TEST DETAILS
ID_Motor_Coil	PS=AC,V=20.8,I=0.03636	IDLE	NA	ID_Motor_Test
ID_1st AUX_UVR-T_Coil	PS=AC,V=22,I=0.007211	IDLE	NA	ID_1st AUX Shunt_Test
ID_2nd AUX_Shunt_Coil	PS=AC,V=22,I=0.006818	IDLE	NA	ID_1st AUX Shunt_Test

Fig. 4 ID Test 1

TEST NAME	TEST PARAMETER	TEST STATUS	TEST RESULT	TEST DETAILS
ID_Motor_Coil	PS=AC,V=20.8,I=0.03636	1	I=20.935700,R=0.994474	ID_Motor_Test
ID_1st AUX_UVR-T_Coil	PS=AC,V=22,I=0.007211	1	I=0.556000,R=39.586331	ID_1st AUX Shunt_Test
ID_2nd AUX_Shunt_Coil	PS=AC,V=22,I=0.006818	0	NA	ID_1st AUX Shunt_Test

Fig. 5 ID Test 2

Figure 4, shown above, is a picture taken during the ID Test. Three Coil MLAB codes are publicly available for decoding. It has 5 Columns: Test Name, Test Parameter, Jest Status, Test result, and Test details. The first column is the Bayer of the Coil inside the ACB, for example, the 1st AUX Release=UVR-t and the 2nd AUX Release=Shunt Trip. Moreover, Spring Charging Motor & AUX 2nd Columns will have Test Parameters for Example 208-240 VAC/ 220-250 VDC 3rd column will have Test Status 4th column will have Test Result 5th column will have Test details for example ID-MOTOR-TEST fail.

Figure 5: The above image is the ACB ID Test Failed report. When giving PS=AC, V=22,1=0.006818 in ID 2nd AUX Shunt Coil in three Coil inside ACB, it is TEST RESULT Current and Resistance is not coming, so ID 2nd AUX Shunt Coil is not working. So, the TEST STATUS is 0. Reset Fail will, therefore, show even if two out of three work. The image above shows the ACP ID test results.

TEST NAME	TEST PARAMETER	TEST STATUS	TEST RESULT	TEST DETAILS
ID_Motor_Coil	PS=AC,V=20.8,I=0.03636	1	I=20.935700,R=0.994474	ID_Motor_Test
ID_1st AUX_UVR-T_Coil	PS=AC,V=22,I=0.007211	1	I=0.556000,R=39.586331	ID_1st AUX Shunt_Test
ID_2nd AUX_Shunt_Coil	PS=AC,V=22,I=0.006818	0	NA	ID_1st AUX Shunt_Test

Fig. 6 ID Test 3

The three coils give the same output for the input, so it passed the test shown in Fig 6. This ACB will proceed to the next test.

4.3 HIGH VOLTAGE TEST

The high voltage test finds the ACB incoming and outgoing terminals. When applying high voltage, it works appropriately. For example, is the connection

HV TEST DETAILS 2

TEST NAME	TEST STATUS	MEASURNMEN	TEST CASE	PARAMETER	TIME OUT
L1&L2	OPEN	0.2kvA	100mA	IDLE	
L1&L3	OPEN	0.2kvA	100mA	IDLE	
L2&L3	OPEN	0.2kvA	100mA	IDLE	
L1&T1	OPEN	0.2kvA	100mA	IDLE	
L2&T2	OPEN	0.2kvA	100mA	IDLE	
L3&T3	OPEN	0.2kvA	100mA	IDLE	
L1&G	CLOSE	0.2kvA	100mA	IDLE	
L2&G	CLOSE	0.2kvA	100mA	IDLE	
L3&G	CLOSE	0.2kvA	100mA	IDLE	
L1&L2	CLOSE	0.2kvA	100mA	IDLE	
L1&L3	CLOSE	0.2kvA	100mA	IDLE	
L2&L3	CLOSE	0.2kvA	100mA	IDLE	

Fig. 7 High Voltage Test 1

secure between these two terminals by applying high current? In this test, any short circuits used during manufacturing can be found. This test is conducted under two conditions: ACB open circuit state and ACB closed circuit state.

Figure 7: The above image is an ACB high-voltage test. In this test, it can be seen whether the main ACB terminal is properly made without any chart circuit. So, we can see if all terminals are working correctly by giving high power. This test has five columns: TEST NAME, STATUS, MEASUREMENT, TEST CASE, and PARAMETER. In the 1st column, there will be TEST NAME, which means the Name of the Main Terminal. In the 2nd column, the TEST STATUS is there, and it can be seen that the Test Terminal is taken with Open Status or Close. 3Th Column MEASURNMEN indicates the power we input in the Test, for example, 0.2kvA 4Th Column TEST CASE In this input. The current value is shown for Example 100mA 5Th Column test status. Whether passed or failed, these can be seen in the ACB Main Terminal Test. For example, Result 0 means Test Fail, and 1 means Test Pass.

Figure 8: The above image shows the ACB high voltage test results in the Close State. ACB failed this high-voltage test. There is a short circuit between all main terminals so the Test Status will be 0. SO, THIS ACP HIGH VOLTAGE TEST FAIL.

HV TEST DETAILS

TEST NAME	BREAKER STATUS	SET VOLTAGE	SET CURRENT	TEST STATUS	LEAKAGE CURRENT	CH STATE	CH NO
L1&L2	OPEN	0.2kvA	100mA	1	I=0.000017	HIGH,LOW	101,102
L1&L3	OPEN	0.2kvA	100mA	1	I=0.000014	HIGH,LOW	101,103
L2&L3	OPEN	0.2kvA	100mA	0		HIGH,LOW	102,103
L1&T1	OPEN	0.2kvA	100mA	0		HIGH,LOW	101,201
L2&T2	OPEN	0.2kvA	100mA	0		HIGH,LOW	102,202
L3&T3	OPEN	0.2kvA	100mA	0		HIGH,LOW	103,203
L1&G	CLOSE	0.2kvA	100mA	0		HIGH,LOW	101,301
L2&G	CLOSE	0.2kvA	100mA	0		HIGH,LOW	102,301
L3&G	CLOSE	0.2kvA	100mA	0		HIGH,LOW	103,301

Fig. 8 High Voltage Test 2

L1&L2	OPEN	0.2kvA	100mA	1	I=0.000017	HIGH,LOW	101,102
L1&L3	OPEN	0.2kvA	100mA	1	I=0.000014	HIGH,LOW	101,103
L2&L3	OPEN	0.2kvA	100mA	1	I=0.000000	HIGH,LOW	102,103
L1&T1	OPEN	0.2kvA	100mA	1	I=0.000014	HIGH,LOW	101,201
L2&T2	OPEN	0.2kvA	100mA	1	I=0.000015	HIGH,LOW	102,202
L3&T3	OPEN	0.2kvA	100mA	1	I=0.000016	HIGH,LOW	103,203

Fig. 9: High Voltage Test 3

Figure 9, Above image is ACB high voltage test results in Close and open State ACB has failed in this high voltage test NO SHORT CIRCUIT BETWEEN ALL MAIN TERMINALS TEST STATUS IS 1 . SO THIS ACP HIGH VOLTAGE TEST pass.

5. Conclusion

This study has highlighted the exclusive capability of Siemens air circuit breakers (ACB 3wJ and 3WT) to undergo testing with the ACB Testing Machine. It underscores the limitations of ACP machines, which can only be tested by Siemens, indicating a potential area for future research and development. The paper also emphasizes the need for comprehensive testing of circuit breakers from various companies to ensure their quality and reliability. While the focus has been on ACB low-voltage breakers, it is important to note that many companies utilize other types of circuit breakers, such as Vacuum Circuit Breakers, SF6 Circuit Breakers, Oil Circuit Breakers (OCB), and Medium Voltage and Voltage Circuit Breakers. These, too, warrant rigorous testing to ascertain their performance and safety standards. Moving forward, the scope of this work could be expanded to include the testing of these diverse circuit breakers, thereby contributing to the broader goal of enhancing the safety and efficiency of electrical systems. This would benefit the industry and serve the larger interest of consumer safety and satisfaction. Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First, use the equation editor to create the equation. Then, select the "Equation" markup style. Press the tab key and write the equation number in parentheses.

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