Creation of Electrical Life Test with integrated temperature data logging as per IEC-60947-4-1

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***Abstract*-This paper is part of a study conducted at Siemens R&D test lab for low voltage switchgear equipments as per IEC Standards. Testing plays a pivotal role in both pre and post manufacturing of a product .The goal of this study is to make the testing process reach its optimum level by making the test cells obtain real time data, have less conduction time within minimum space and minimum cost. After a thorough analysis of the various tests carried out in the test lab, the Electrical endurance test viz. an Accelerated life test was found to be the most time consuming and indispensable test. The main reason behind the life test taking the large conduction time is due to its conduction along with a cyclic temperature rise test .The temperature rise test is conducted on a product undergoing a life test after certain stipulated number of operations of the life test. The problems faced in this method of conduction, in addition to its large time consumption, are the difficulty in obtaining real time temperature rise data, space consumption and cost incurred in the setting up of an additional test cell. Hence to overcome the aforesaid issues it is proposed to integrate the two test cells viz. the Electrical Endurance test cell and temperature rise test cell by conducting the temperature rise test in the same cell as that of the life test. The study focuses on the possible methods of integrating the two test cells. A feasibility study is conducted on the possible test circuits that can be implemented for integration .The most feasible circuit is chosen and the test results are compared with that of the conventional method to further assert that the integration of the two test cells have aided in achieving our objectives.**

Keywords-Testing, Electrical Endurance test, Temperature rise test, Integrate, optimization

I. INTRODUCTION

Siemens Ltd has a dedicated Research and Development (R&D) department for the testing of their various engineering products like switchgear equipment, motors, transformers etc. Low voltage switchgear equipment such as contactors, miniature circuit breakers (MCBs), moulded case circuit breakers (MCCBs) are tested in the R&D test lab. The two main tests conducted in the R&D lab-i) Performance test(accelerated life test, basic parameter test and short circuit test) ii) Environmental test (Mechanical shocks and vibrations test, temperature rise test). The equipment undergoing these testing procedures is termed as the Equipment under Test or EUT. The EUT chosen for this study was an S-12 Contactor (Size 12).The parameters and IEC standards chosen are with respect to the S-12 contactor. Since the EUT is an AC-3 duty contactor, the IEC standards applicable for it is IEC-60947-4-1.The number of operating cycles for an AC-3 duty contactor is 1 million operations with 750 operations/hour.

II. BACKGROUND

Accelerated life testing is the process of testing a product by subjecting it to condition in excess of its normal service parameters in an effort to uncover faults and potential modes of failure in a short amount of time. From the above mentioned tests, the Electrical endurance test viz. an Accelerated life test was found to be the most time consuming and the most indispensable test. The conduction of the endurance test in alternate cycles along with the temperature rise test (T.R) was the main reason behind its longer span of conduction. Due to their indispensability the optimization of these two tests is the primary focus of the paper.

A. Electrical Endurance Test

The two types of accelerated life testing conducted on low voltage switchgear at Siemens are –Electrical endurance test and Mechanical endurance test. As per IEC standards if an Endurance test is being conducted as a type test the equipment need to be subjected to a certain number of operations which extends to its end of life. The test is conducted on the EUT with two backup supplies- one for providing the making current and the other for providing the breaking current. The parameters measured in the Electrical endurance test are the making and breaking current. The single line diagram of the Endurance test is depicted in Fig.1. For an AC3 duty contactor having two backup supplies , backup supply B1 is switched on first provide the making current to the EUT, it is followed by the switching on of EUT. Some milliseconds later B1 is switched off and after a time delay, backup supply B2 is switched on which provides the breaking current to the EUT. The EUT is switched off and some milliseconds later, B2 is switched off. The timing diagram of the test is shown in Fig.2.The delay provided to the two backup supplies and the EUT is controlled by a programmable logic controller(PLC).The PLC used for this study is a Siemens Logo PLC.Fig.2 represents the timing diagram of an AC-3 duty contactor.

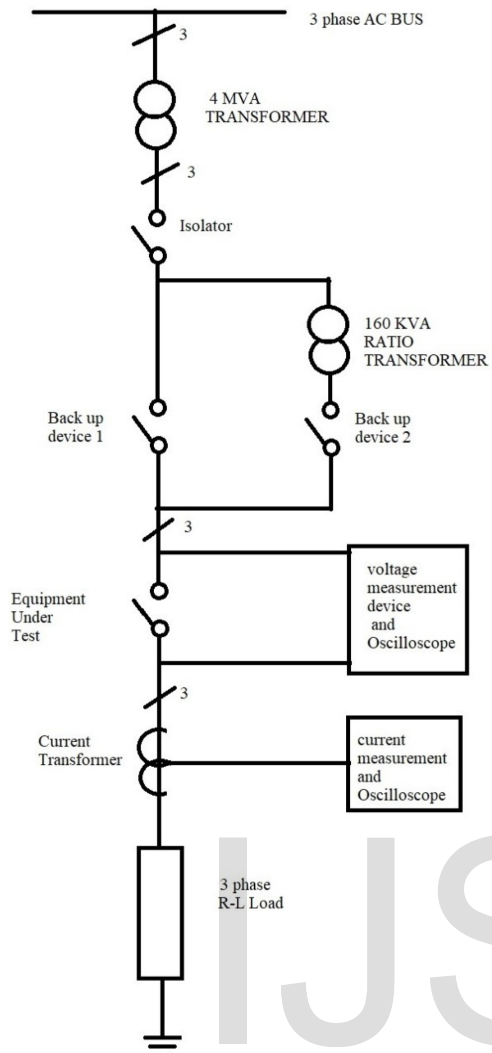


Fig.1 Single line diagram of Electrical endurance test

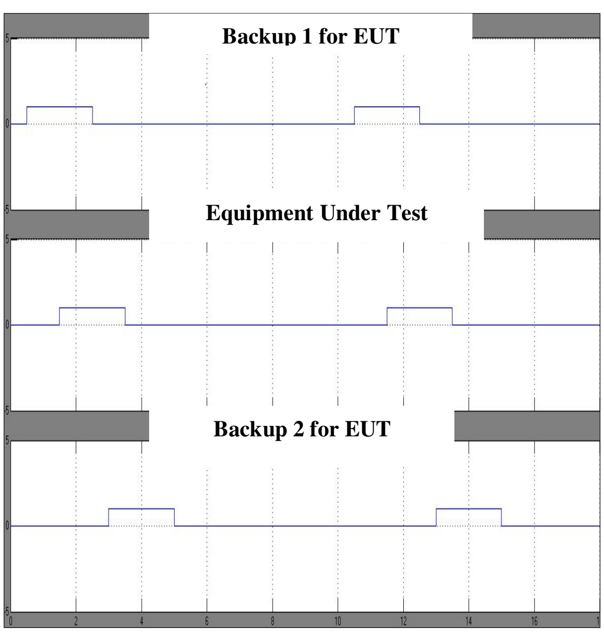


Fig.2 Timing diagram for Electrical endurance test on an AC-3 duty contactor

B. Temperature Rise (T.R)Test

The temperature rise test is carried out five times in between the electrical life test in a separate cell by transferring the equipment from one test cell to the other. This test is conducted on the EUT by attaching thermocouples viz. a temperature transducer to the both current conducting and non-conducting parts of the device. The thermocouples are attached to a data logger(MW100 YokoGawa) .The data logger continuously records the corresponding temperature rise and the current in the various parts of the device. It is conducted at five time intervals of 20%, 40%, 60%, and 80% of the total number of operating cycles of the Endurance test.

C. Conduction Of The Tests

The conventional method of conducting these two tests alternately gives rise to the following problems:

- An increase in the overall test time of the Electrical Endurance test- Each cycle of the T.R test takes 3 days to complete. Hence for 5 test cycles of the T.R test, a total of 15 days is required for this test alone. This additional test time causes an additional requirement of manpower for supervision and an overall delay in the testing process
- An inability to represent the data in real time-In the process of transferring the EUT from one test cell to the other the parameters measured in the T.R test may vary and may not give accurate results.
- An increase in overall cost due to the setting up of separate test cells-Due to the additional space requirement for the T.R test , the cost also thereby increases.

III. OBJECTIVE

The aim of this study is to find a solution to the problems encountered in the conventional method of conducting the Electrical endurance test. The key objectives that we would want to achieve through this study are:

- To save the time of conduction
- To improve the quality of data obtained
- To make the conduction of electrical endurance test more economical

To achieve the above mentioned objectives the integration of the temperature rise test cell along with the existing endurance test cell was thought to be a feasible solution to the problem. This involves the simultaneous conduction of both the tests on the same EUT in the same test cell.

IV. METHODOLOGY

The two methods that have been analyzed for measuring the temperature rise during electrical endurance test are the non-contact method and the contact method. The main parameters on which feasibility of the test circuit was checked were- cost, level of accuracy of data, ease of implementation and interface requirement (such as a data logger).

A. Non Contact Method

The non contact method eliminates the use of a temperature transducer (i.e. a J type thermocouple in the conventional setup)

,which is connected directly to the various parts of the contactor, including its live parts. In this method the devices used for measuring the temperature rise doesn't have any physical contact with the Equipment under test (EUT), instead the distributed heat concentrations of various parts of the EUT are captured using devices such as thermal camera and infrared camera. In this method, the complete electrical isolation of the two test cells is possible. Notwithstanding this method has a disadvantage of not having an interface for continuous data recording in addition to high initial cost and lower levels of accuracy in the data obtained.
To counter the drawbacks of the non contact method, the contact method was proposed.

B. Contact Method

In this solution the temperature rise test is performed along with the Electrical endurance test by connecting a suitable temperature transducer such as a thermocouple to the conducting and non conducting parts of the contactor and feeding the corresponding voltage to the data logger which will indicate the real time temperature rise of the contactor. The two test circuits analysed were –

1. Differential amplifier circuit –conduction of T.R test during the ON time period of the EUT
2. Relay circuit- conduction of T.R test during the OFF time period of the EUT

The electrical Endurance test has an ON time period ranging from the time the first backup device is switched on to the time the second backup device is switched off. During this time period the EUT passes the making and breaking current through its contacts. Since complete electrical isolation is not obtained during the ON cycle due to the live parts of the EUT, a differential amplifier is used.

A differential amplifier is a type of electronic amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs. The differential amplifier was connected between the thermocouple terminals and the multimeter (analogous to data logger). The output of the differential amplifier gave the differential output in mill volts corresponding to temperature rise in the thermocouple terminals. the differential amplifier was used in the unity gain closed loop form and hence it gave the difference of the input voltages at its output end with a gain equal to 1. This voltage was fed directly to the data logger between two terminals of single channel, which could handle voltages up to 10V.

Problems encountered in using a differential amplifier circuit are:

- While implementing this circuit a separate ground needs to be created (floating ground). This increases the complexity of the circuit.
- The distance constraint of the thermocouple terminals prevents it from being implemented.

To counter the problems mentioned above the

The OFF cycle time corresponds to the time period ranging from the time the second backup is switched off to the switching on of the first backup device. The integration is done during this time by providing a relay circuit as the backup device, which will keep the contactor terminal energized. This circuit provides electrical isolation between the two test cells since one test is completely independent of the other test. The circuit is less complex and economical.

Hence after the feasibility analysis this circuit was considered to be the most feasible one

C. Relay Circuit For Integration

The integration of the two test cells with the help of a relay circuit involves a Programmable Logic Controller (PLC) controlled relay which governs the operation of two auxiliary contactors (K1 and K2). One end (Hot junction) of thermocouple is connected to the EUT (Equipment under Test) and the other end (Cold Junction) is placed on the terminals of the auxiliary contactors. The terminals of auxiliary contactors in turn connected to the MW 100 data logger.

Selection of relay and auxiliary contactors is done based on its response time, coil current (pick up), dimensions and the cost. The relay was chosen on the basis of its pickup current; the pickup current is supposed to be less than the PLC output current. Similarly the auxiliary contactors are also selected based on the relay's output current (wherein auxiliary contactor pickup current < relay output current).The relay chosen is the Phoenix Contact 2961105 Relay and the auxiliary contactors are 3TH30 Contactors. The relay circuit for integration is depicted in Fig.3 and Fig.4

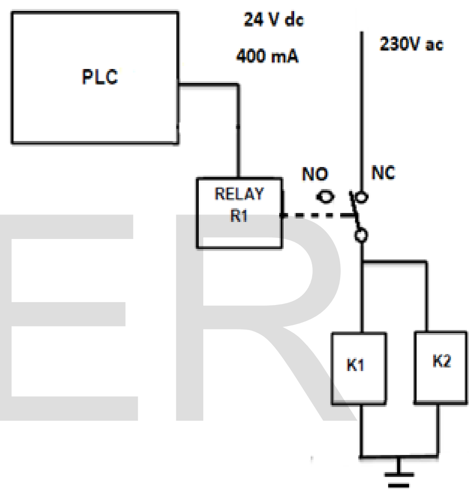


Fig.3 Power circuit for the relay integration unit

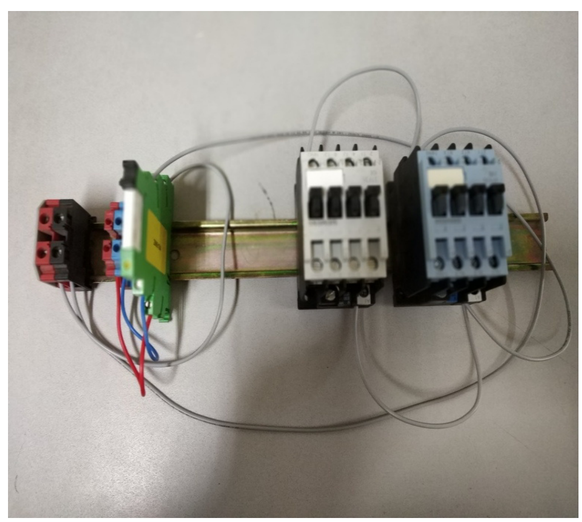


Fig.4 Relay circuit mounted on a DIN rail

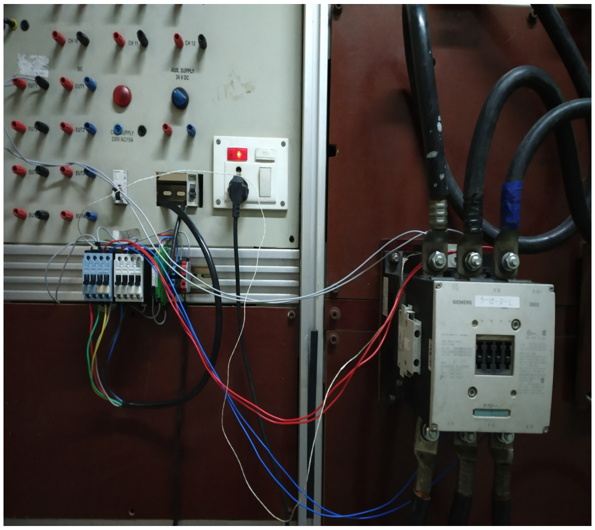


Fig.5 Actual setup on S12 -RT1076 contactor with relay integration unit

The PLC is programmed in such a way that the relay circuit operates in the time period only when both the backup supplies are OFF. The two auxiliary contactors (K1 and K2) are connected in parallel along with the relay (R1).The coils of the two contactors are energized by a 230V supply. Whenever the backup supply is off, the PLC gives a triggering pulse to the relay which makes the NO terminals to close thereby energizing the auxiliary contactors through 230V.The actual test circuit is depicted in Fig.5 and the timing diagram for this test circuits is depicted in Fig.6

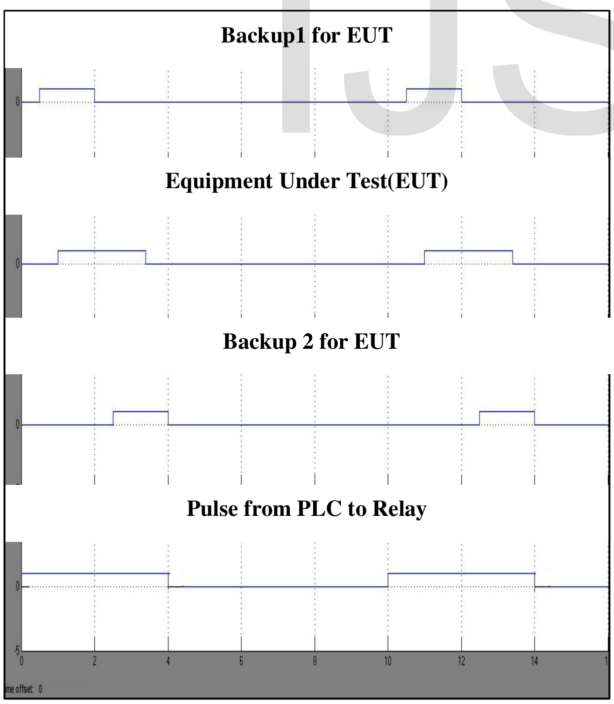


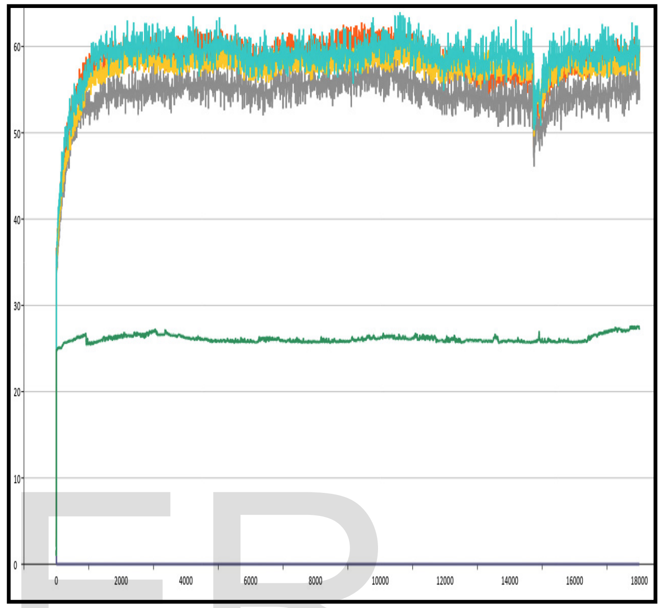
Fig.5 Timing diagram of the actual setup on S12 -RT1076 contactor with relay integration unit

V. TEST RESULTS

A. Analysis Of Data (obtained from T.R test)

The product used for testing was an S12 -RT1076 contactor having a life of 1million operations. And an operating frequency of 750 operations/hr .The Electrical endurance test was carried out at a current of 500A and the cyclic temperature rise at 610A as per IEC standards for AC-3 duty contactors..The make current was 6 times the rated for a duty cycle of 0.08 and the break current for a duty cycle of 0.05 .For the electrical endurance test. the rms (root mean square) equivalent value of current is calculated from the formula :

Rms current I_{rms}= operating current* [duty cycle/(3600/operating frequency)]$^{1/2}$



Legend:
L2-TER-C1 **T2-TER-C1**
L2-TER-C2 **T2-TER-C2**
Ambient

Fig.7 Temperature variation in the EUT recorded by the relay integration setup

The graph shown in Fig. 7 represents the temperature variations (Yaxis) in the EUT over a period of 24 hours (time-X axis). This temperature rise test data is obtained with the integrated test setup. This data is obtained after 2 lakh operations of the Endurance test viz .20% of 1 million operations(the total life of the contactor).The temperature rise is calculated from the time wherein the instantaneous temperatures enter a stable region or become a constant value.

The temperature rise of the terminals located in the middle i.e. L2 & T2 of the two contactors (C1 & C2) under test is measured since they have the highest heat accumulation as compared to any other parts of the contactor. The temperature rise is due to the heating by I^2R losses. The term R is dependent on cable size, tightening torque, contact résistance. In both the tests, these factors are considered to be constant. Since both these tests are carried out at different values of current in conventional practice there is difference in the I^2R values which is calculated and used to obtain expected values for the integration test. A comparison of the temperature rise test values obtained from the integrated and conventional test setup is shown in Table I.

TABLE I. COMPARISON OF TEMPERATURE RISE IN THE CONTACTOR

Method of Temperature Rise measurement	L2 Terminal Temperature in °C	T2 Terminal Temperature in °C
Conventional	31.1	28
With Integration (Proposed)	31.4	29.6

The variation in data between two methods was found out to be 1%-6% due to the difference in current and ambient temperatures. Other factors such as cable size, tightening torque, contact resistance remained the same. Thus we can obtain the temperature rise during endurance test by keeping a tolerance level of ± 10% variation in calculation.

B. Analysis of Conduction Time

The conduction time (in days) required for an Electrical endurance test is calculated as follows:

$$\text{No of days} = \frac{\text{Total no of operations}}{\text{(No of operations per hour* No of hours)}} = \frac{1*10^6}{750*24} = 55 \text{ days}$$

The time incurred for the conduction of only the electrical endurance test was 55 days.In the conventional method the cyclic temperature rise test takes 15 days (The time involved for transferring the product from one test cell to the other along with the setting up of the test cell's parameters as per product's requirement has also been considered).Hence the total test in the conventional method is 70 days. The temperature rise test alone takes 27% of the total test time.

In the integrated test setup the total conduction time was 55 days i.e the number of days required by the electrical endurance test.Due to the simultaneous conduction of the tests, a sving of 15 days was obtained.

C. Analysis of Cost

The cost incurred for the temperature rise test facility is depicted below:

Cost involved= (Rent for testing facility + No of days for Temperature rise measurements* Cost for a technician per day)

=(10000+12*500)

= Rs.17500

Table II depicts the comparison between the cost and time savings in the conventional and the integrated setup.

TABLE II. COMPARISON OF TIME AND COST SAVINGS IN THE TWO METHODS

Method of Testing	Time requried(in days)	Cost savings(in Rs.)
Conventional	70	-
Proposed	55	17500

VI. CONCLUSION

The objective of this study was to develop a test unit which carry out two tests i.e. Electrical endurance test and temperature rise test simultaneously without compromising on the following

- Electrical isolation between two tests,
- Quality of data acquired,
- Ease of implementation

The method used for integration requires modification of PLC program to overcome time delay associated with integration unit, and a few modifications in test setup of electrical endurance test to occupy the integration unit and the data logger.

In terms of cost comparison the integration was found to be economical. There was also a significant time savings found in the integrated test setup and the temperature rise data obtained was found to have a constant percentage variation with respect to the conventional test setup.

Hence it can be concluded that the integration of the two test cells for the purpose of optimization of the overall testing process was a feasible solution to the problems encountered in the conventional setup.

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