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A study of failure analysis in SF_6 circuit breaker

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The circuit breaker of SF_6 type has many advantages over conventional type, being better performance and dielectric properties. SF_6 circuit breaker are now being employed widely in substations for better electrical network functioning. Even then, it is associated with some failures which are reported in the field. Two kinds of circuit breaker are studied in this work with point of thermal behavior. A rated current is passed through SF_6 circuit breaker and thermal mapping is recorded at incoming terminal and outgoing terminal, enclosure and other points for investigations. The steady state condition of temperature is taken as reference in finding temperature rise over the environment condition. The temperature at predecided points of circuit breaker both for passed sample and failed sample are recorded. The data obtained is analyzed and attempt is made to understand the failure of SF_6 breaker in the context of excessive temperature than the prescribed limits of International Specifications. This paper deals with sample arrangement, experimental details, results and analysis. Both failed sample and passed sample have shown contrast performance in final analysis.

Keywords: *Circuit breaker, temperature, thermal mapping, steady state, SF_6 gas, thermocouples.*

1.0 INTRODUCTION

Different methods are available for assessing the electrical equipment in new and in service electrical equipment. In this direction, electrical condition is assessed by the methods such as voltages withstand ability, insulation resistance, Dielectric tests and others. The thermal condition of electrical equipment is equally tough in evaluation of electrical equipment thermally. For complete evaluation of electrical equipment, it is essential to find integrity of equipment with respect to electrical, mechanical, thermal and electro chemical. Conventional methods of infrared spectroscopy will give the condition of temperature when electrical equipment is exposed to the thermal camera. It will reveal temperature record on the surface of the equipment such as bushings, CT's and related accessories. However it will not penetrate into the electrical equipment under observation and will not be able to reveal temperatures inside the equipment. In this context, temperature rise method is useful by employing thermocouples to the sample whose status is to be established.

Thermal mapping will include temperature record at different locations of electrical equipment. The temperatures are monitored with respect to environment in the laboratory at the instant of data recording [4]. This method is convenient in monitoring temperature inside the electrical equipment such as SF_6 circuit breaker under study. It is essential to monitor the thermal condition of SF_6 breaker in operation conditions as it is excessive temperature which will trigger the failure of electrical equipment at installation as well as in operation. With these points in view, in laboratory two samples of SF_6 type circuit breaker are subjected to experiments thermally.

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A method of current passage [5], monitoring of temperature at predeterminent locations of SF_6 circuit breaker which are critical and important in finding the thermal status of SF_6 circuit breaker. Attempts are made to understand thermal distribution, thermal mapping in the operation of SF_6 circuit breaker. SF_6 is the best dielectric medium among the gaseous insulators and it is widely used in electrical equipment for better insulation properties. The dielectric strength of SF_6 is found to be four folds that of nitrogen [1]. In this study, attempts are made to understand thermal functioning of SF_6 circuit breaker. Two interesting cases such as failure one and pass case of SF_6 circuit breaker are studied in this research paper.

2.0 EXPERIMENTAL DETAILS

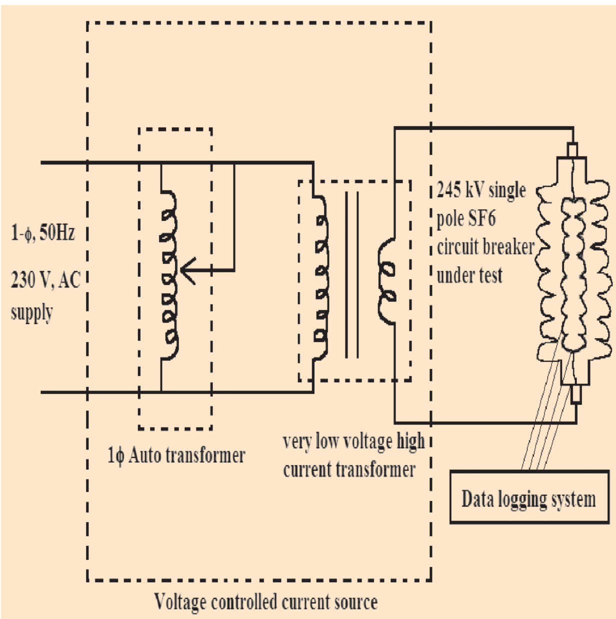

FIG. 1 EXPERIMENTAL ARRANGEMENT FOR HEAT RUN TEST ON SF6 CIRCUIT BREAKER

The experimental setup consists of the current source, regulator, sample and data capturing system. The measurements are made with temperature rise method using thermocouples [4]. This method has advantage over other prevailing methods because of its versatility in measuring temperature at different parts inside of completely enclosed electrical equipment. In this method, thermocouples are used to capture temperatures in various positions of equipment [5]. Thermocouples used are T type made of copper constant and have an adequate measuring temperature range and precision of measurement. The Figure 1 displays the complete layout arrangement of apparatus in the experiment. The current source used is low voltage high current source of rating 1ϕ, 50 Hz, 230 V auto-transformer with current transformers whose output capacity of 4000 Amps. A regulation of capacity 150 kVA is employed to adjust required current from the current source. The circuit breaker employed is 245 kV, 4000 Amps SF_6 circuit breaker for the study. A software operated auto data capturing device would collect temperature data from different locations of SF_6 circuit breaker connected in the circuit. Two samples of SF_6 circuit breaker are used for study. The thermocouples are connected from the sample to modules of data system which has four numbers of modules and electrically linked with measuring parts of the sample and data acquisition system. A current of 4000 Amps is passed through the system and temperatures are recorded at regular intervals of half an hour still steady state. When the temperature of the sample is steady, the temperature at individual points at steady state and ambient temperature of the laboratory are considered to find the increase in temperature of the component and temperature rise is computed. The temperature rise at different points are thus mapped to obtain thermal mapping of both the samples of failure and passed ones.

3.0 DETAILS OF RESULTS AND ANALYSIS

The data obtained from the experiment conducted as in the previous paragraph.

The results for top terminal pad, fixed contact support, crown, cylinder top, moving contact, bottom terminal pad and SF_6 gas has shown the values in Table 1 at steady state of circuit breaker. The Table 1 shows the maximum values at steady state both for passed case as well as failed case. Bottom terminal pad has shown strikingly high magnitude of temperature. This value is also excess of normal permitted values as well as at other points considered for the study.

In all the cases, the difference in temperature rise in both cases is found to be more than 14°C which is the significant factor in determining the condition of the sample. Figure 2 to Figure 9 represent the variation of temperature with duration for all the critical points of circuit breaker studied. Figure 8 shows a huge difference of temperature between passed sample and failed sample. Figure 8 describes temperature trend for SF_6 gas inside the equipment. The difference in temperature up to 200 mins from the commencement of experiment is insignificant. The difference in temperatures for two samples gradually rises and at steady state of 390 mins shows the value of 20°C which indicates definite indication of excessive temperature condition of circuit breaker. Although this temperature of 80°C is not an index for SF_6 circuit breaker healthiness, this temperature of 80°C will promote excessive temperature distribution for other parts of circuit breaker. The Figure 10 indicate column charts for all components of circuit breaker during experiment when thermal equilibrium is achieved. In all the cases it was found that failed sample exhibited higher temperature with respect to passed sample as well as with respect to permissible values of international specification IEC 62271-1-2011 [2][3].

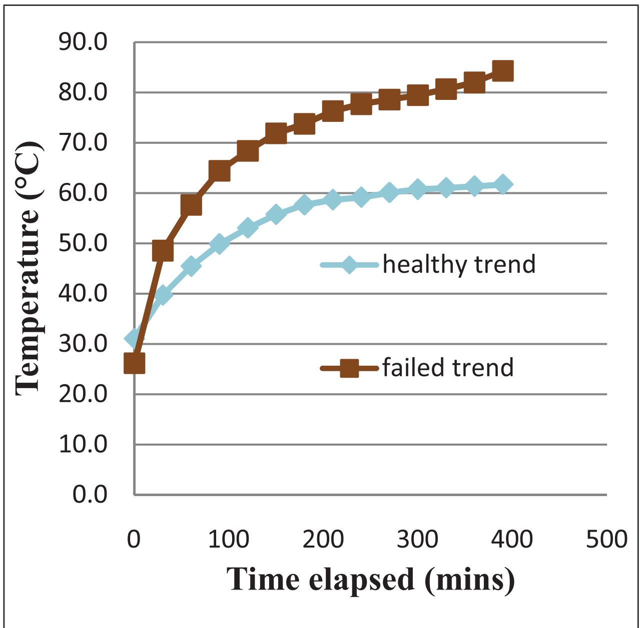

FIG. 2 THE VARIATION OF TEMPERATURE WITH TIME FOR TOP TERMINAL PAD

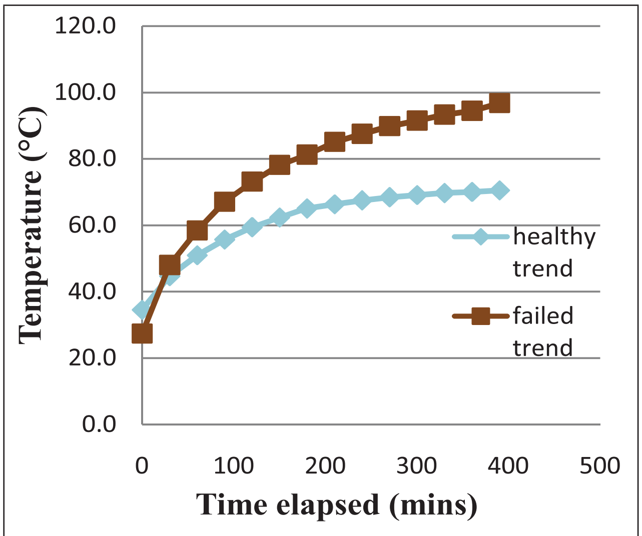

FIG. 3 THE VARIATION OF TEMPERATURE WITH TIME FOR FIXED CONTACT SUPPORT

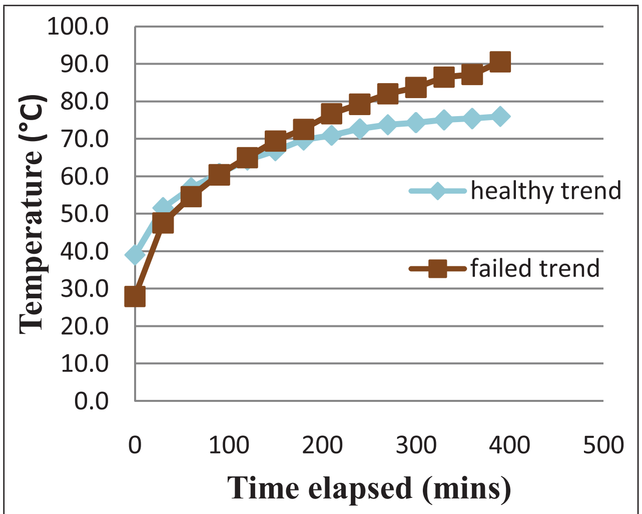

FIG. 4 THE VARIATION OF TEMPERATURE WITH TIME FOR FIXED CONTACT KEPT VERY NEAR TO CROWN

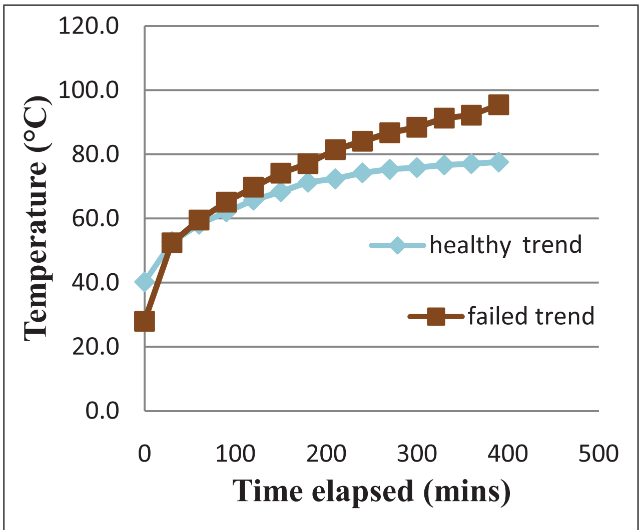

FIG. 5 THE VARIATION OF TEMPERATURE WITH TIME FOR CYLINDER TOP

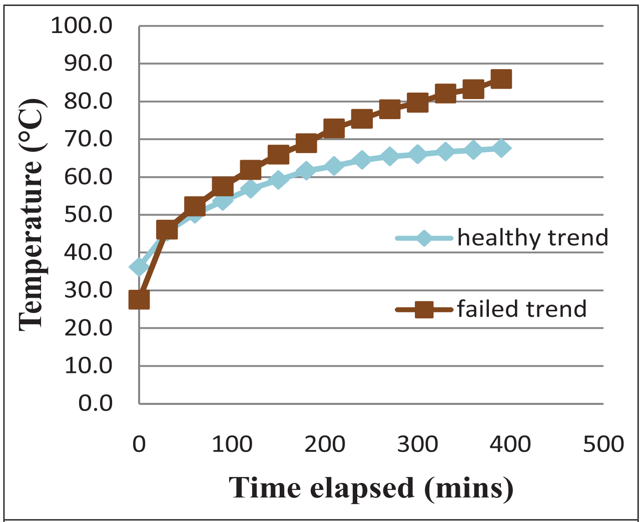

FIG. 6 THE VARIATION OF TEMPERATURE WITH TIME FOR MOVING CONTACT KEPT VERY NEAR TO CROWN

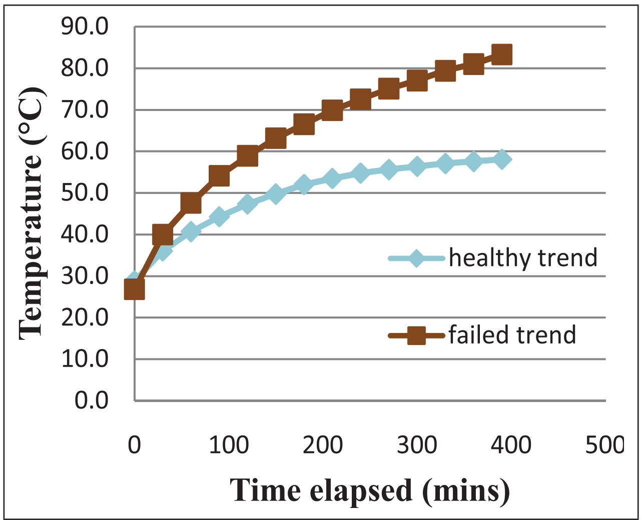

FIG. 7 THE VARIATION OF TEMPERATURE WITH TIME FOR MOVING CONTACT SUPPORT TOP

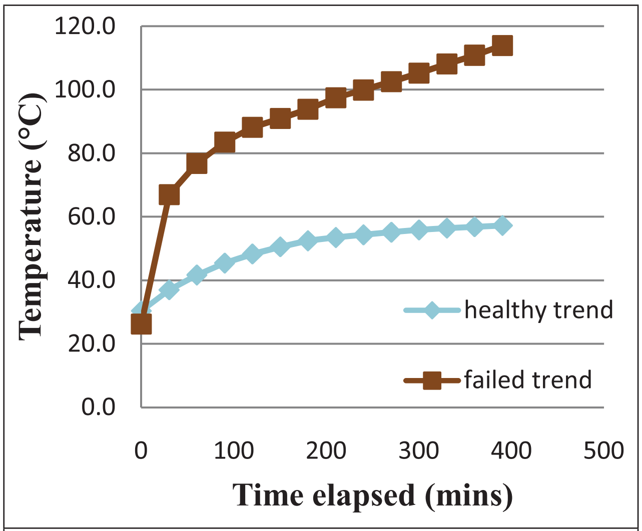

FIG. 8 THE VARIATION OF TEMPERATURE WITH TIME FOR BOTTOM TERMINAL PAD

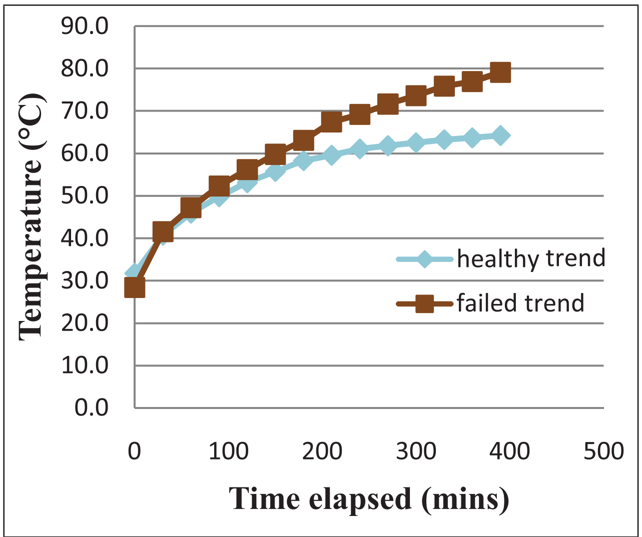

FIG. 9 THE VARIATION OF TEMPERATURE WITH TIME FOR SF6 GAS

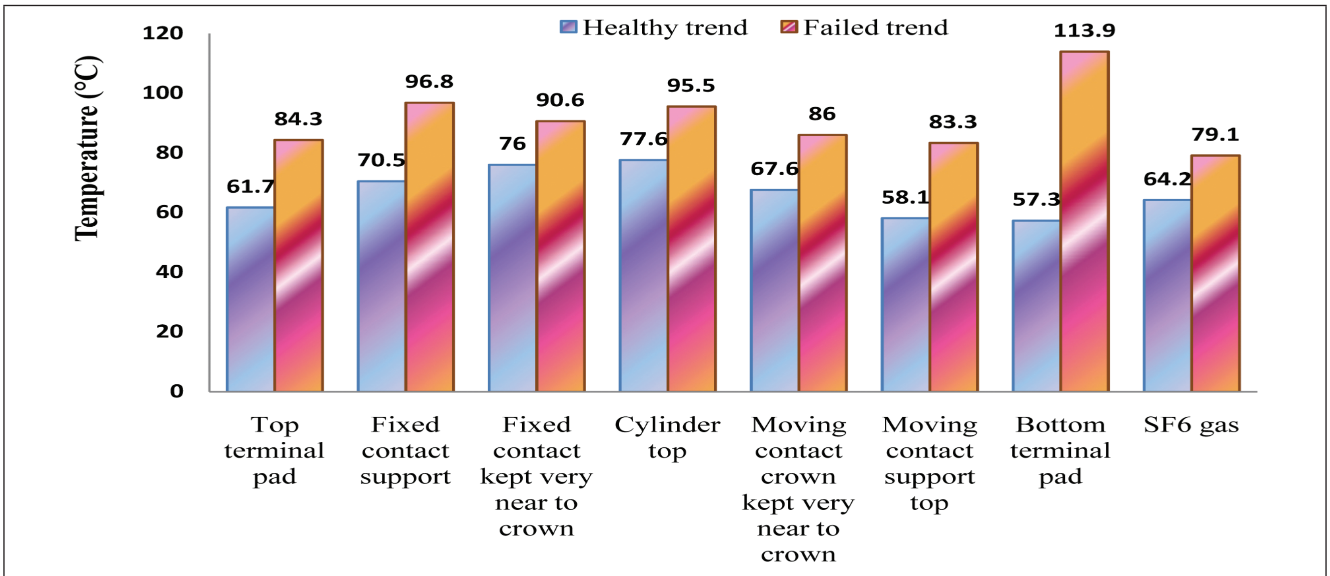

FIG. 10 COMPARISON OF TEMPERATURE VALUES DURING TEMPERATURE RISE TEST

TABLE 1

TEMPERATURE DATA FOR PASSED AND FAILED SF6 CIRCUIT BREAKER

Sl. No.	Parameters	Maximum value (°C) (passed)	Maximum value (C) (failed)
1	Top terminal pad	61.7	84.3
2	Fixed contact support	70.5	96.8
3	Fixed contact kept very near to crown	76.0	90.6
4	Cylinder top	77.6	95.5
5	Moving contact crown kept very near to crown	67.6	86.0
6	Moving contact support top	58.1	83.3
7	Bottom terminal pad	57.3	113.9
8	SF_6 gas	64.2	79.1

Table 2 refers to thermal condition of different parts of circuit breaker for failed sample and passed sample quantitatively and diagrammatically presented in Figure 11 to Figure 13. The results obtained during the experiment of temperature rise test on circuit breaker is quantitatively described in Figure 11 to Figure 13. Figure 11 refers to initial state of the circuit breaker temperature vise. Both temperatures of failed sample and passed sample are considered and their respective values and trend are mentioned in the Figure 11 for terminal pad, cylinder and contacts including the surrounding environment of SF_6.

Figure 12 refers to thermal state of circuit breaker and their components at intermediate point of the experiment. The temperatures of failed sample and passed sample are presented. Finally Figure 13 represents the final thermal state of SF_6 circuit breaker when steady state is reached mentioning all the components and their respective temperatures for both passed sample and failed sample. From the above three figures it can be seen that the temperatures of components in failed sample are higher than the passed case in the intermediate and final steady state of the experiment.

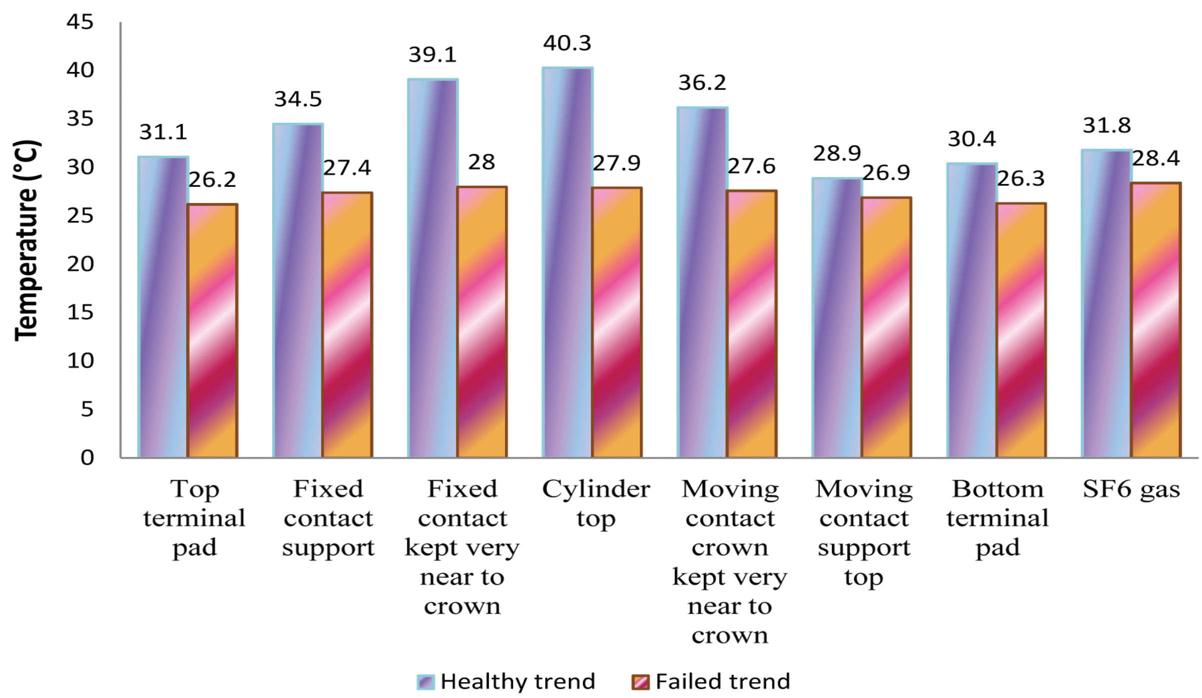

FIG. 11 COMPARISON OF TEMPERATURE VALUES DURING TEMPERATURE RISE TEST AT INITIAL STATE

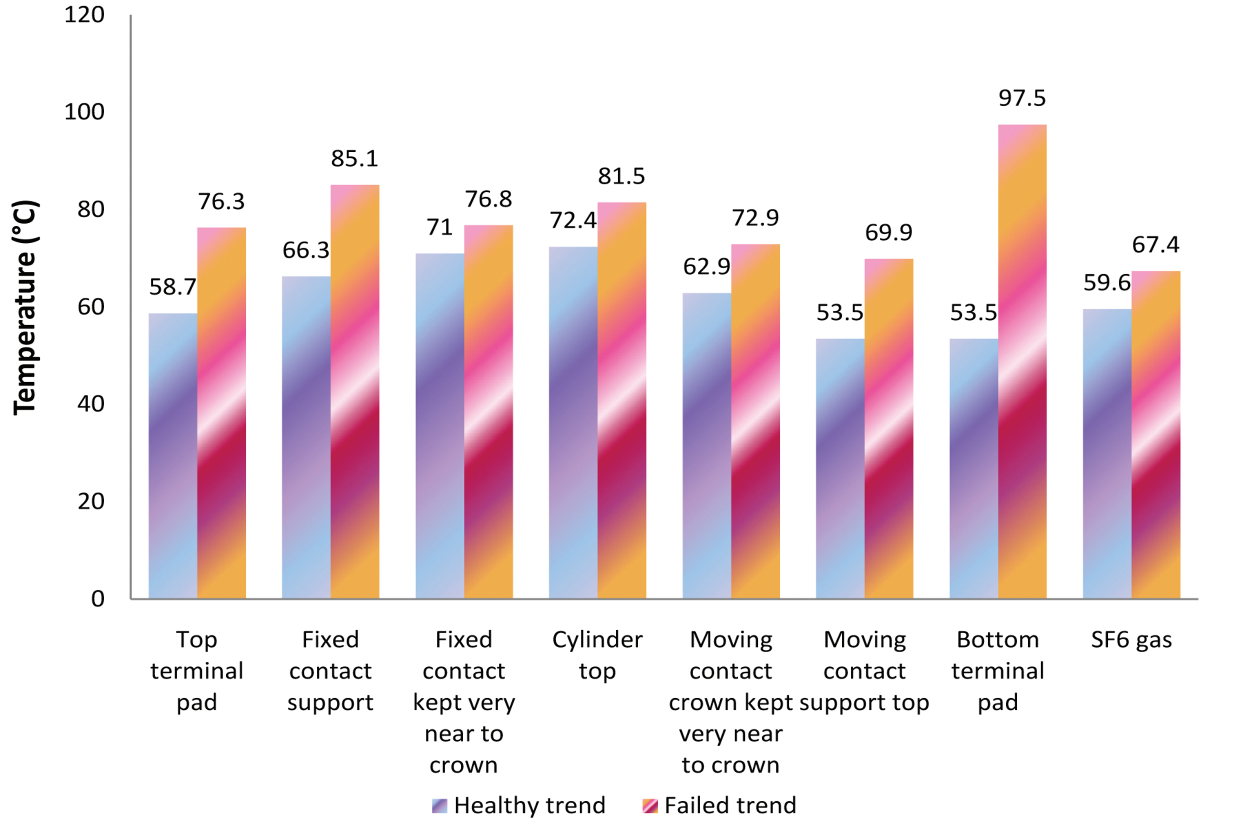

FIG. 12 COMPARISON OF TEMPERATURE VALUES DURING TEMPERATURE RISE TEST AT MIDDLE STATE

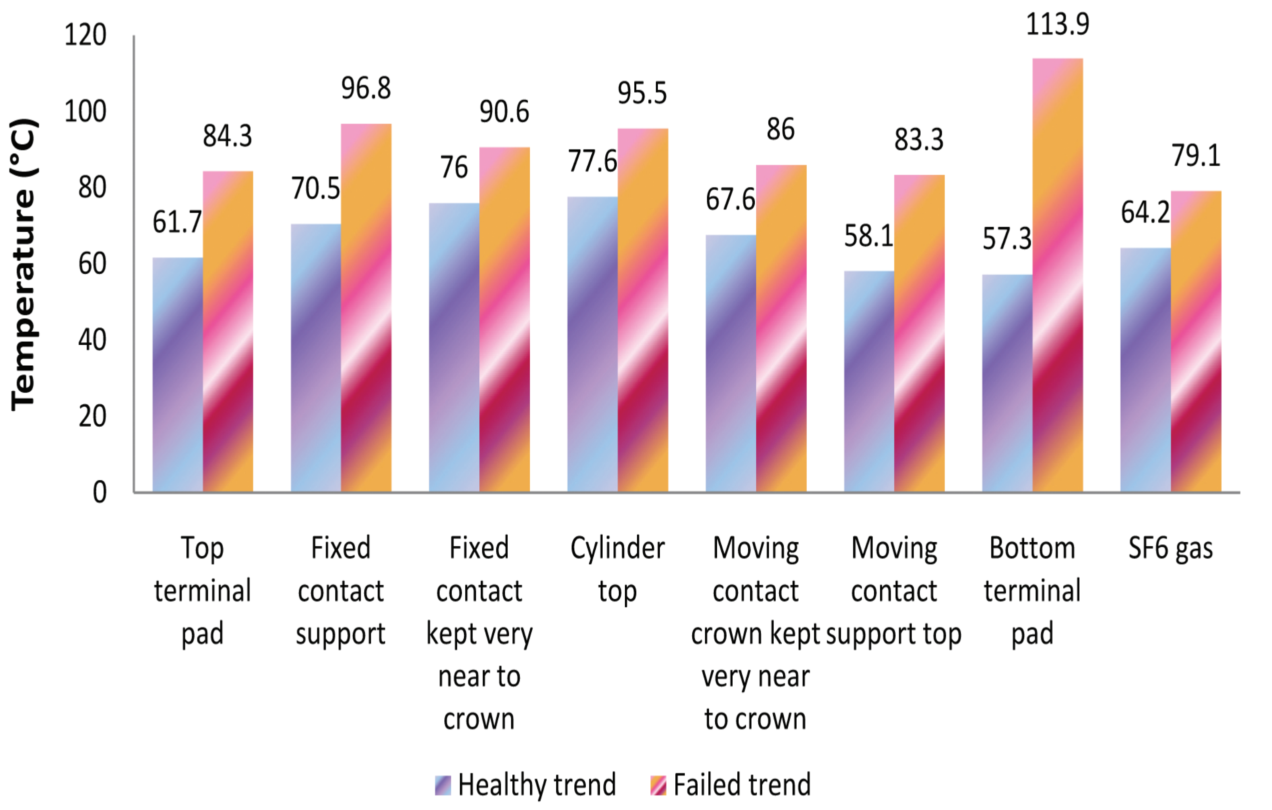

FIG. 13 COMPARISON OF TEMPERATURE VALUES DURING TEMPERATURE RISE TEST AT STEADY STATE

TABLE 2							
TEMPERATURE DATA FOR PASSED AND FAILED SF6 CIRCUIT BREAKER							
Sl. No.	**Parameters**	**Passed case**			**Failed case**		
		Initial state	**Intermediate state**	**Steady state**	**Initial state**	**Intermediate state**	**Steady state**
1	Top terminal pad	31.1	58.7	61.7	26.2	76.3	84.3
2	Fixed contact support	34.5	66.3	70.5	27.4	85.1	96.8
3	Fixed contact kept very near to crown	39.1	71.0	76.0	28.0	76.8	90.6
4	Cylinder top	40.3	72.4	77.6	27.9	81.5	95.5
5	Moving contact crown kept very near to crown	36.2	62.9	67.6	27.6	72.9	86.0
6	Moving contact support top	28.9	53.5	58.1	26.9	69.9	83.3
7	Bottom terminal pad	30.4	53.5	57.3	26.3	97.5	113.9
8	SF_6 gas	31.8	59.6	64.2	28.4	67.4	79.1

From above results it is clear that abnormal excessive temperature is the cause for abnormal thermal performance of SF_6 circuit breaker though SF_6 is very good insulating medium. Hence it is to be accounted for in the design and material aspects for terminal pad, moving contact and fixed contact which have to be critically examined.

4.0 CONCLUSIONS

Based on the results obtained the following inferences are made from SF_6 circuit breaker.

- Although SF_6 insulating medium is used it is important that material aspects of fixed contact and movable contacts are to be examined.
- Bare conducting materials castoff in the contact assembly inside the SF_6 circuit breaker chamber must sustain without annealing in the opearing temperatures upto 75 °C.
- Bottom terminal pad of SF_6 circuit breaker is more vulnerable for excessive temperature.
- Design and suitable materials are to be accounted in SF_6 circuit breaker depending on current rating although SF_6 is used.

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[5] IEC 61439-1-2011 Low-voltage switchgear and control gear assemblies- Part1: General rule.