The Journal of CPRI,
Vol. 10, No. 2, June 2014 pp. 309-314

Thermal Performance of Low Voltage Power Distribution Board Panel (PDBP) at Elevated Temperature

Viswanatha C*, Vittal G P** and Mohanbabu V***

Thermal performance has been the subject of studies for LV equipment since decades and continues to be the established practice to assess its continued usage of the equipment in service or installation in the case of newly designed equipment. The PDBP being core of the distribution network to deliver reliable quality power is investigated for its performance in ambient temperature and at elevated temperature. Although, the equipment behavior is known at ambient temperature, its performance at elevated temperature of 55˚C is seldom studied. Recently, the temperature in the globe is on the raise leading to global warming and in addition there is requirement in industrial applications and high temperate zones. The feasibility of electrical equipment in this elevated temperature condition is not known. In this context, the equipment has been subjected to laboratory studies. The data obtained showed the interesting results such as need of thermally endured materials in the configured system of the equipment. The operation of the equipment in elevated temperature will accelerate deterioration and reduction in the service life of the equipment. However, proper thermally endured components, thermal design of the equipment will ensure for the application of the equipment in the elevated temperature. The method of Temperature monitoring of the equipment by subjecting to service condition of operating temperature and current can be applied as a means to study the thermal performance of equipment. These aspects of the experimental method, the results obtained at ambient and elevated temperature are discussed and investigated in this research work.

Keywords: *Thermal, elevated temperature, Distribution Board, ageing, insulators, Temperature rise.*

1.0 INTRODUCTION

Reliable operation without unplanned interruptions is expected to be performed by Power Distribution Board Panel (PDBP) and is essential requirement for modern power distribution network. PDBP is also core infrastructure in critical electrical systems where it has to deliver high quality of power consistently, efficiently, safely in all types of environment. With increase in demand for power have made stringent requirements on modern low voltage (LV) control and distribution boards which have to be easily integrated into distribution cabinet and systems. Recent times, there has been rapid growth in variety of Distribution Boards in respect of Planning, design, Compactness besides maintaining reliable and standard compliance in quality. The modern design have brought about LV power distribution is flexible, easy and at the same time fast in integration of unit to a particular application. The recent technology development made the made maintenance after installation in the field is quite simple, comprehensive. It is well established practice that Distribution Boards / network are almost applied in every installation of industrial, infrastructure and Buildings. Also, Distribution Board needs to ensure flexibility and economic power distribution in any application

*Author for correspondence HRT laboratory, DCCD, Central Power Research Institute, Bangalore - 560080. India
Mobile: +91 9482732239, Email: viswa@cpri.in
**HRT laboratory, DCCD, Central Power Research Institute, Bangalore - 560080, India. Email: vittal@cpri.in
***HRT laboratory, DCCD, Central Power Research Institute, Bangalore - 560080, India. Email: mohanvasu@cpri.in

and over its entire life cycle. For consistent, safe and intelligent power distribution, Distribution Board has to function and perform well in all environment/ operational stresses to achieve a steady reliable supply of electric power. In case of fault on the busbar in DB, one half of substation will be switched off and power supply will be interrupted [7]. It is in this context, it is necessary to study the thermal performance of Distribution Board (DB) which has direct bearing on its functionality. Any disruption or failure even for a short a while of operation of distribution Board would lead to consequent failure of power supply in the electrical network / system.

Among various operational stresses, it is temperature stress on the equipment / Distribution Board plays dominant role in the thermal performance and its consequent healthy operation in the power system. The temperature is the important parameter to monitor the state of functioning of the sample. Hence, the thermal performance of LV Distribution Board is to be understood besides other design requirements to a satisfactory operation in service. The planning, configuration design and integration is crucial in reliable and safe operation of Distribution Board for uninterrupted power supply. In this study, the effect of ambient temperature and at the elevated temperature on Distribution Board has been undertaken to study and understand thermal performance in terms of temperature and temperature rise at various designated points in the configuration of distribution board. The selected points of study to monitor temperature are so designed to cover entire configuration of the sample and at the same time give a satisfactory frame work to understand the thermal performance /dynamics of the sample during experiments deigned and conducted.

2.0 EXPERIMENTAL WORK

The experiments have been conducted on the sample comprising of various components at ambient temperature (RT) and in specially designed oven at elevated temperature (ELT). The sample chosen for the study is SMSB (sub main switch board). It is of type Distribution Board with rating of 415 V, 320 A and 50 Hz. The rated insulation voltage is 690 V for this distribution board. The internal configuration of SMSB with main busbars and CB is shown in the Figure 1 with relevant details of its constituents. The overall dimensions of the sample under investigation are 900 mm width 1750 mm height & 500 mm depth. The support insulators are made of Epoxy insulation with height of 50 mm and its rated insulation of 690 V. The incoming circuit has MCCB, rated current of 400 A, rated voltage of 415 V, 3 Poles and 50 Hz. The outgoing has four sub circuits each circuit has MCCB rated current 100 A, 415 V and the interconnecting busbars is of 1Rx30x10mm.

2.1 Method

Thermocouple method of recording and monitoring of temperatures at designated points of sample is adopted [1]. Thermocouples of T type have been employed. A data recording system is connected to computer and sample, through thermocouples is the experimental arrangement. The temperatures are recorded with accuracy of 0.1°C. The temperature at the interval of half an hour has been measured in all cases of the experiments. The experiment of temperature rise has been continued for the period of 5-6 hours till thermal equilibrium is obtained. At this point, it is said that the sample has attained thermal steady state.

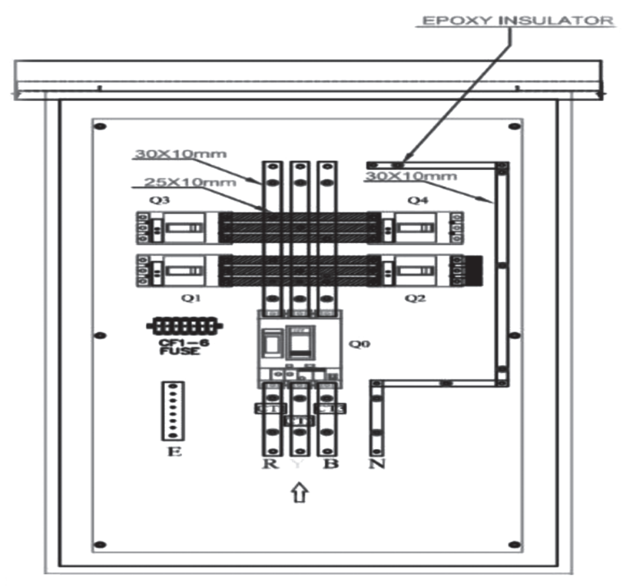

FIG. 1 PLATE VIEW OF THE EQUIPMENT DB INTERNAL STRUCTURE

The criterion of the steady state is that at the interval of 1 hour duration, there is no temperature increase of more than one degree centigrade [6]. All the critical components of thermal performance have been chosen before the commencement of experiment. A Rated current of 320 A is passed into the sample under study through 5000A, 20V current source using suitable cross section copper braids connected to it.

The Figure 1 shows the elements comprising of the sample. Chosen thermocouples have been fixed at designated points Figure 2 describes the location of thermocouples during temperature rise test on 320 A Distribution Board.

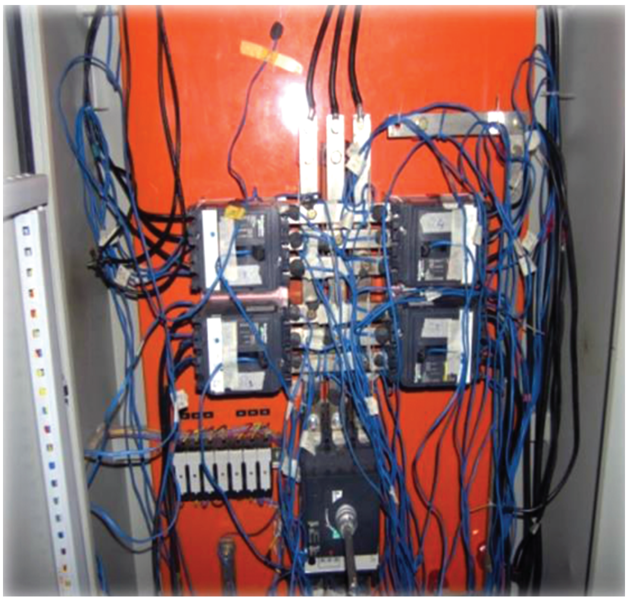

FIG. 2 LOCATIONS OF THERMOCOUPLES FOR MEASURING TEMPERATURE

FIG. 3 DISTRIBUTION BOARD UNDER TEST ASSEMBLE INSIDE AN HOT OVEN

To start with, experiments are conducted at ambient temperature (RT).Then the sample is mounted in specially designed oven which can maintain the temperature to 0.1˚C accuracy. Figure 3 depicts the mounting arrangement and measurement at ELT (elevated temperature of 55 degree centigrade).

3.0 RESULTS AND DISCUSSIONS

The configuration of the sample under investigation has been considered into the following elements for compilation of data and consolidation of the experimental results.

1. Main Breaker incoming terminal (M1)
2. Main Breaker outgoing terminal (M2)
3. Busbar joint1 (M3)
4. Busbar joint2 (M4)
5. Internal Temperature of panel (M5)
6. Insulators (M6)
7. MCCB (M7) and
8. Panel incoming terminal (M8)

The temperature recorded at these identified points of measurements is compiled. The data has been collected for the experiments conducted at the temperature of ambient (RT) 25˚C and elevated temperature (ELT) 55˚C.

The experimental data has been examined in the context of ambient temperature and elevated temperature. The trend in the characteristics of temperature and duration of the experiment is similar in both the cases and some interesting features of the trend are obtained.

At room temperature, the temperature of the component/point increases with time initially rapidly, then gradually towards steady state where equilibrium state is obtained. The rate of rise and slope of the characteristic curve depends on the configuration. The thermal profiles of all the component of the sample are shown in the following figures. It can be inferred from the characteristic of thermal profile of insulator is high relative to that of MCCB enclosure. This is due to insulation properties of epoxy insulator and insulation enclosure of MCCB (M7). Also it was observed that for a particular component under study, the thermal profile is similar in nature for all three phases R, Y and B considered. In all the cases the steady state has been achieved after 5 hours duration.

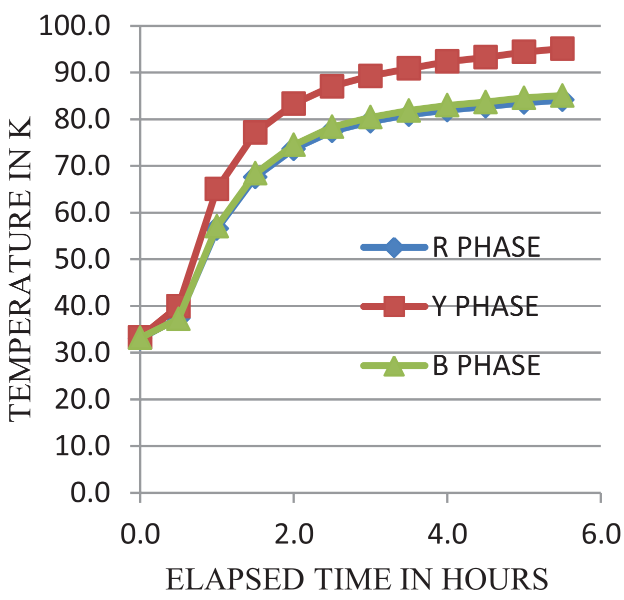

FIG. 4 THERMAL PROFILE OF PANEL INCOMING TERMINAL

Figure 4 shows the characteristics of temperature and duration for panel incoming terminal

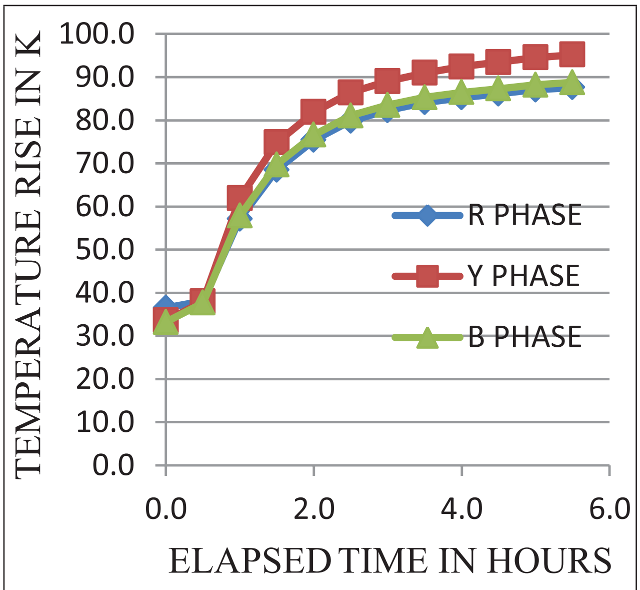

FIG. 5 THERMAL PROFILE OF MAIN BREAKER INCOMING

Figure 5 shows the characteristics of temperature and duration for Main Breaker incoming.

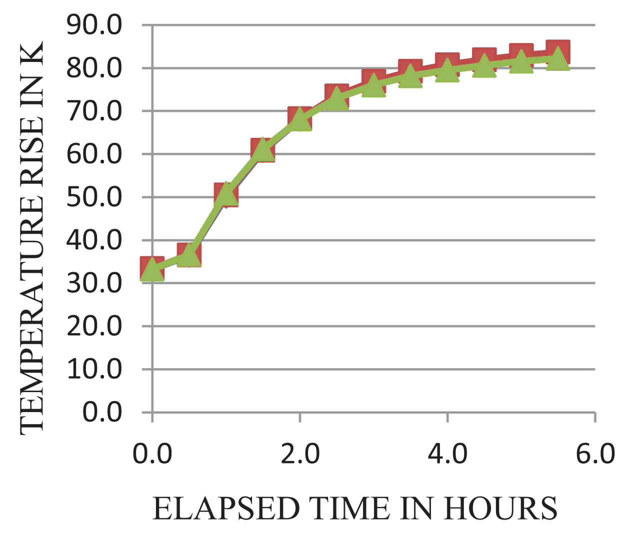

FIG. 6 THERMAL PROFILE OF BUSBAR JOINTS

Figure 6 shows the Characteristics of temperature and duration for Busbar

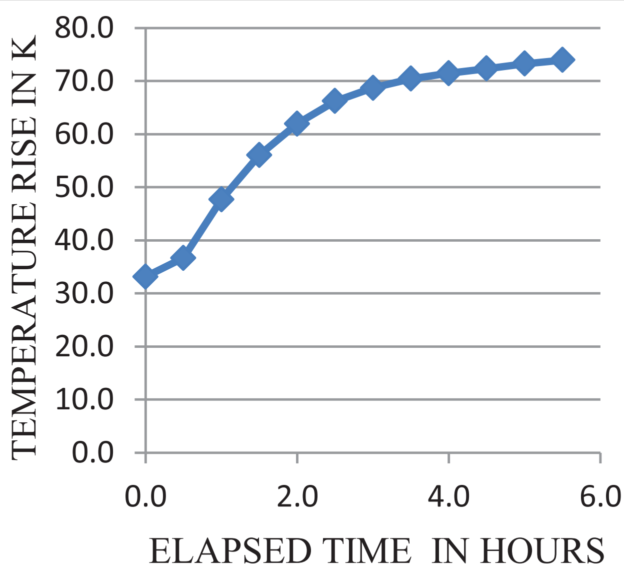

FIG. 7 THERMAL PROFILE OF SUPPORT INSULATOR

Figure 7 shows characteristics of Temperature and duration for support insulator.

When the sample is subjected to elevated temperature, each component performs differently and the characteristics of temperature and duration of exposure are shown in the Figures. Figure 4 to Figure 8. The initial raise of the curve is rapid till the period of 2 hours, thereafter the curve behaves depending on the type of components (M1 to M8).The trend increases regularly till 4 hours and the rate of rise slows down and a steady state is achieved after duration of 5 hours. At this steady state, also known as thermal equilibrium state, the characteristic curve flattens and remains constant. There is no further significant increase in the magnitude of temperature recorded for specified points. The difference (ΔX) in the magnitudes of the temperature at ambient temperature and elevated temperature at steady state have been presented in the following Table 1.

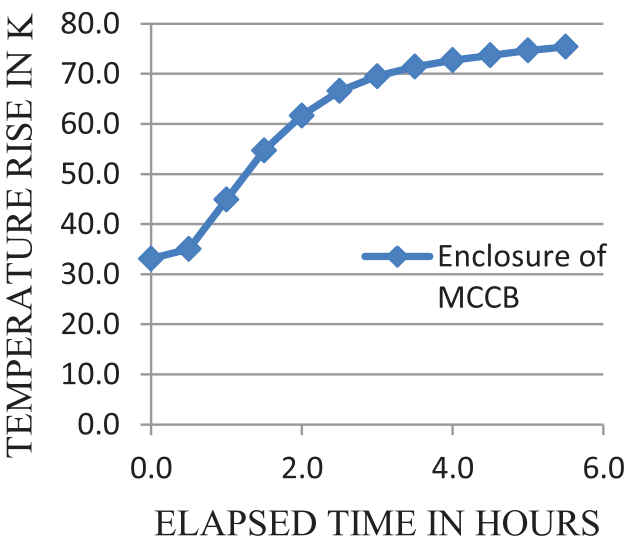

FIG. 8 THERMAL PROFILE OF MCCB ENCLOSURE

Figure 8 shows the Characteristics of temperature and duration For MCCB.

From these results it is clear that though the environment of elevated temperature is 55˚C, the internal temperature rises to high value of 66.3˚C, this is because of the fact that heat dissipation occurs due to other surrounding components and further dynamics of Heat. The characteristics of the point (M5) are rapid rise for 3.5 hours, then gradual increase for stabilization value. The enclosure of MCCB (M7) shows high magnitude of ΔX indicating that it is susceptible elevated temperature.

From the table1 it is clear that the ΔX 25˚C to 30˚C means that at elevated temperature exposure, the thermal stresses will be 2.5 to 3 times accelerated compared to ambient temperature operation of the sample. Therefore, it is imperative to employ high temperature resistant materials at the sensitive configuration of the sample. The temperature difference ΔX for MCCB striking result indicating requirement of proper enclosure at this point. In all, it can be observed that elevated temperature environment contributes to acceleration of the deterioration in the performance of the sample. This further confirmed form the data obtained from these experiments and results are consolidated in the following Table 2.

TABLE 1

THERMAL PROFILE AT ELEVATED TEMPERATURE

Sl No.	Configuration	Temperature difference at steady state (ΔT)˚C
1	Main Breaker incoming terminal (M1)	27
2	Main Breaker outgoing terminal (M2)	30
3	Busbar joint1(M3)	30
4	Busbar joint2(M4)	27
5	Internal Temperature of panel(M5)	25
6	Insulators(M6)	29
7	MCCB (M7)	42
8	Panel incoming terminal(M8)	29

3.1 Observations

Temperature Rise at ambient and elevated temperature:

The performance of temperature rise values for the various components of the sample has been studies for the ambient temperature (RT) and elevated temperature (ELT). The data for both RT and ELT has been analyzed and the interesting points have been obtained [3-5]. The rise values of temperature at RT are higher in magnitude than the corresponding values of rise at ELT (elevated temperature). The Table 2 shows decrement values ΔY in relation to RT and ELT in evaluation of the thermal performance of the sample.

TABLE 2

THERMAL PARAMETERS

Sl No.	Particulars of configuration	Decrement ΔY = TH-To
1	Main Breaker incoming terminal (M1)	4.0
2	Main Breaker outgoing terminal (M2)	5.2
3	Busbar joint1(M3)	5.0
4	Busbar joint2 (M4)	5.2
5	Internal temperature of panel (M5)	5.5
6	Insulators (M6)	1.2
7	MCCB (M7)	1.4
8	Panel incoming terminal (M8)	2.0

Compared to values of ELT and ambient temperature values, the decrement is considered as ΔY. Interestingly negative values have been obtained for the components of the sample. The decrement is found to be 5˚C for most of the components except for the points of M7 and insulator M6. This is due to the insulation nature of the component and M6 is epoxy insulation and good thermal class insulation [2] and hence elevated temperature performance of M6 is not significant. These results suggest that constant exposure of equipment to high temperature of ELT will provide accelerating deterioration of the components. Although Temperature rise limits at elevated temperature environment are lower, the high magnitude of ELT will accelerate deterioration mechanisms and ageing of the components of the sample. This will ultimately reduce length of service of sample and consequent chain reactions of failure by accelerated ageing. This results in manifestation of premature failure/breakdown of the sample than planned/designed service life.

4.0 CONCLUSIONS

Detailed investigation at RT and ELT of the sample points out the following important inferences of the experiments conducted in the laboratory:

1. Thermal performance of the sample at elevated temperature reduces its operational service period because of acceleration of deterioration effects of elevated temperature.
2. For enclosures of MCCB in the sample, thermal resistant material will ensure proper endurance at ELT.
3. Proper selection and employment of the materials for components comprising of sample is to be exercised and it will provide a long way in thermal performance of unit especially at elevated temperature to its full operational capacity.

REFERENCES

[1] IEC 61439-Part1: 2011, “Low voltage switchgear and control gear assemblies”

[2] Broad well, “A book on Electrical insulation” 1985

[3] Y G Painthankar and S R Bhide, “ A book on Fundamentals of Power System protection”,

[4] Sunil S Rao, “ A book on Switchgear Protection and Power Systems” 2008

[5] Badriram & Viswakharma, “A book on Power System Protection & Switchgear” 2001

[6] IS 8623-Part1 1993/IEC 60439-Part 1 1985 RA-2004, “Low voltage switchgear and controlgear”.

[7] S L Uppal, “Electrical Power ” 2009.