International Journal of Multidisciplinary Research and Modern Education (IJMRME)
ISSN (Online): 2454 - 6119
(www.rdmodernresearch.org) Volume II, Issue I, 2016

THERMAL ANALYSIS OF BUS-BAR FOR SWITCH BOARD

Krishna Dwivedi*, Kulwant Dhankar, Smita Ganjare*** & Hemant More******

Assistant Professor, Mechanical Department, LTCOE, Navi Mumbai, Maharashtra

Abstract:

In an electric power system, switchboard is the combinations of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. In development of low voltage switchboard, proper thermal design becomes more important to provide safe function and reliability. Due to the high complexity of heat generation and loss processes it is not easy to predict the thermal behaviour of devices under various load conditions. This paper based on experimental as well as simulation based model to develop most optimum design. It combines analytical experimental and simulation based data to optimize design. This study involves temperature predictions by modeling the circuit breaker and the bus bar arrangement in the ventilated enclosure to arrive at the optimum current values. It also includes setting derating factors for busbars.

Index Terms: Thermal Analysis, Circuit Breaker, Bus Bars, Switch Gear & Etc

1. Introduction:

With ever increasing growth in energy needs the requirement for a safe, reliable & efficient power distribution is becoming more and more challenging. Switch board which is very critical component in energy distribution. So its design has great impact on overall distribution system. Main objective of this project is design optimization for improving performance reliability and safety of switchboard. Main objective of any switch board design is that all its components will operate in temperature conditions that are less restrictive than those laid down by their construction standards and The scheduled current must obviously be able to flow through the connection switchgear (circuit-breakers, contactors, etc.) without any problem. And this is verified by conducting different test on switchboard. To perform such tests, physical prototypes are first built. However very often in the case of switch board the time & cost associated with product development is huge for each test. So practically it is not possible to make actual model for various combination.

According to characteristics, the current strength/temperature pair for each heat source (switchgear - conductors) in accordance with their position and with the temperature of the surrounding air. It is obvious that simulation tools allow comparative study of the many possible installation configurations and thus optimization of the future switchboard as regards thermal aspects and Cost.

With rapid growth in computational abilities, multi-physics simulation to predict product performance and to perform design optimization has emerged as more acceptable approach in electrical industries. With help Thermal simulation tool it is possible to predict its future operational Performance of product.

2. Heat Transfer Mechanism in Switch Board:

The thermal behaviour of any system, including an electrical switchboard, can be described in terms of heat exchanges. Three types of phenomena are involved: Conduction, convection and radiation

Conduction: Transfer of heat inside solid bodies this phenomenon can be divided up into: Simple conduction where the body in question is not a source of thermal phenomena, e.g. conduction inside a wall. Live conduction where heat is created inside the body in question, e.g. a copper bar with an electric current flowing through it. Calculations concerning the transmission of heat by conduction are based on Fourier's law which, for simple geometries, can be resumed by the equation:

$$\Phi ij = (\lambda S / d) \times (Ti - Tj) \text{ where,}$$

F ij : heat flux between two points i and j in W,
λ: Thermal conductivity in W/m °C,
S: area of the heat exchange surface in m^2,
Ti, Tj : temperatures of the two points in °C,
d: distance between the two points in m,
λis characteristic of the conductive medium. Its value depends on temperature but in most cases is considered as constant.
a few values of l in W/m °C Copper = 38,Aluminium = 203

Radiation: Transfer of heat between solid bodies separated by a medium of varying transparency. Such exchanges take place between the surfaces of any bodies facing one another and are represented by fairly complex relationships involving: The emission of the solid, which if considered to be an ideal black body, depends only on its temperature. The nature of the surface of the solid, expressed by its emissivity *e* which reflects the relative ability of a surface to radiate energy as compared with that of an ideal black body under the same conditions.

Convection: The general term of convection in fact covers two different phenomena, which are frequently treated together. Actual convection, which corresponds to a transfer of heat between a solid body and a moving fluid. According to the origin of fluid movement, convection can be natural or forced. However from a practical viewpoint it can be tackled using heat exchange coefficients with expressions involving:

- ✓ Parameters describing the type of fluid flow (velocity, etc.),
- ✓ The physical properties of the fluid (thermal conductivity, dynamic viscosity, thermal capacity, density, etc.)

The diagram below represents the elements making up the system studied: ambient air, enclosure, internal air and the various heat sources. This description of the switchboard thermal state shows that all the exchange phenomena described above must be taken into consideration and are all considerably inter-related.

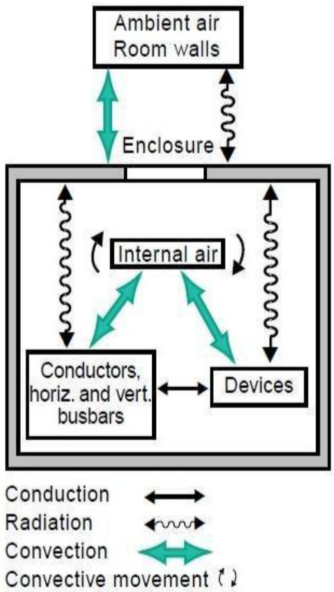

Figure: 1

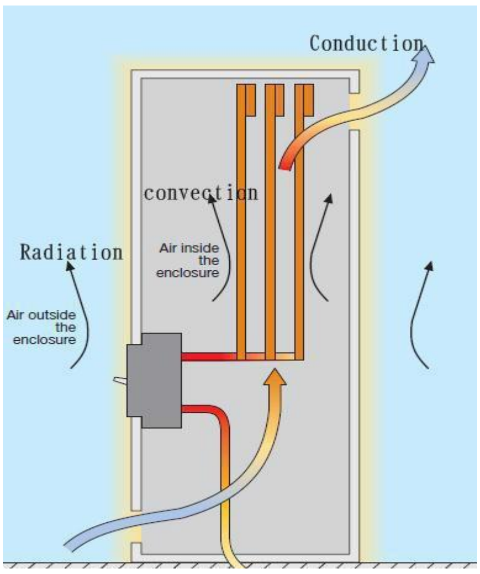

Figure: 2

The internal air temperature results:

- ✓ From exchanges by convection between the internal air and the surfaces of the various devices, conductors and walls.
- ✓ From the heat conveyed by the convective movements of air.
- ✓ For the electrical devices in the switchboard, the heat generated by Joule effect is exchanged:
- ✓ By convection between their heat exchange surfaces and the internal air,
- ✓ By conduction with the bars and cables,
- ✓ By radiation with the enclosure walls and the surfaces of the other devices

3. Bus Bar System:

Bus bar is current carrying device in switch board panel. It is one of the most important devices in power distribution system. Bus bars are used to carry very large currents, or to distribute current to multiple devices within switchboard. Bus bars are made up of Copper or Aluminum.

The cross-sectional size of the bus bar determines the maximum amount of current that can be safely carried. Bus bar shape designed such that ratio of surface area to cross section area is more. These shapes allow heat to dissipate more efficiently. Bus bars are either solid flat strips or hollow tubes. It can be seen that for conductivity and strength, high conductivity copper is superior to aluminum. The only disadvantage of copper is its density; for a given current and temperature rise, an aluminum conductor would be lighter, even though its cross-section would be larger. Temperature limit is much more important for aluminium than copper because it oxidizes very much more readily than copper. The temperature rise of bus bars and conductors is limited by the mechanical strength of the bus bar material, the effect on adjacent equipment, the permissible temperature rise of insulating materials in contact with the bars, and the effect on apparatus connected to the bus bars. Most important factors for efficient bus bar system

- ✓ Provision of a maximum surface area for the dissipation of heat.
- ✓ Arrangement of bars which cause a minimum of interference with the natural movements of air currents
- ✓ Low skin effect and proximity effect for A.C. bus bar systems.

Skin Effect:

An alternating current (A.C.) flowing through an isolated conductor, creates an associated alternating magnetic field. The alternating magnetic flux created by an alternating current interacts with the conductor, generating a back electromotive force (e.m.f.), which tends to reduce the current in the conductor. The e.m.f produced in this way by self-inductance varies both in magnitude and phase through the cross-section of the conductor, being larger in the centre and smaller towards the outside. The current therefore tends to crowd into those parts of the conductor in which the opposing e.m.f. is a minimum; that is, into the skin of a circular conductor or the edges of a flat strip, producing what is known as 'skin' or 'edge effect'.

Derating Factor:

Derating is the reduction of electrical, thermal, mechanical, and other environmental stresses on a part to decrease the degradation rate and prolong its expected life. In case of bus bar system through derating, the margin of safety between the operating current and the permissible current carrying for the part is increased

4. Methodology:

To solve any complex engineering problem following methods plays important role. Analytical method, Experimental method, and Simulation method.

Analytical Method:

The fundamental relationship is that temperature rise is related to the square of the current. Therefore, if the equipment has a certain temperature rise at its rated Continuous current, the current that can be carried continuously in some other ambient temperature can be calculated as a ratio of the squares of the currents.

In mathematical terms:

$$\frac{I_{ambient}}{I_{rated}} = \sqrt{\frac{\theta_{max} - \theta_{ambient}}{\theta_{rated}}}$$

Where,

$I_{ambient}$ = is the current at the actual ambient temperature of the application
I_{rated} = is the rated continuous current at 40°C ambient
θ_{max} = is the maximum allowable temperature for the material involved
$\theta_{ambient}$ = is the actual ambient temperature of the application
θ_{rated} = is the allowable temperature rise for rated continuous current

We calculated from above formula current that can be pass through bus bar at particular temperature i.e. ambient and end temperature

Table: 1

Material	MBB	T1	Test current	40-90 (50)	40-105 (65)	40-115 (75)	50-105 (55)	50 – 115(65)
Al	2x125x6	48.9	2300	2326	2652	2848	2439	2652
Al	2x125x6	54.7	2000	1912	2180	2342	2005	2180
Cu	2x125x6	40.2	3000	3346	3815	2098	3509	3815
Cu	2x125x6	35.4	2500	2971	3388	3639	3119	3388

Experimental Data:

Temperature rise type test has to be performed, in order to make sure that the allowed temperature limits are not exceeded. TRT is conducted to assign the normal current rating to the circuit breaker. The temperature is measured my means of thermocouples or sensors connected to a DAQ system for recording of data. We observed following data from TRT tests

Table: 2

MBB Size	MBB Material	Ambient	End temp.	Test current	Max temp rise MBB
1X125X6	Cu	40	115	1500	58.3
1X125X6	Cu	40	115	2000	61.2
1X125X6	Al	40	105	1500	45.3
1X125X6	Al	40	105	1000	41.8

Simulation Methodology:

Simulation process starts with modelling of assembly. Assembly is simplified without causing any error in simulation process. After modelling assembly, model is properly meshed. Simulation results are affected by type of meshing so selection of proper element and element size gives accurate results. Then boundary conditions such as current, voltage, convection are applied and model is solved for particular boundary condition. Boundary conditions used for the simulation software represent the electrical, mechanical and environmental conditions during temperature rise test. These results are verified with practical data and analytical data. We carried out simulation for Aluminium as well as copper bus bar at different current.

Properties of Copper:

Table: 3

Density	8933 Kg/m^2
Coeff. of thermal expansion	10 $W/m^2/k$
Thermal conductivity	398 W/m/k
Specific heat	385 J/kg/k

Copper at 2000amp

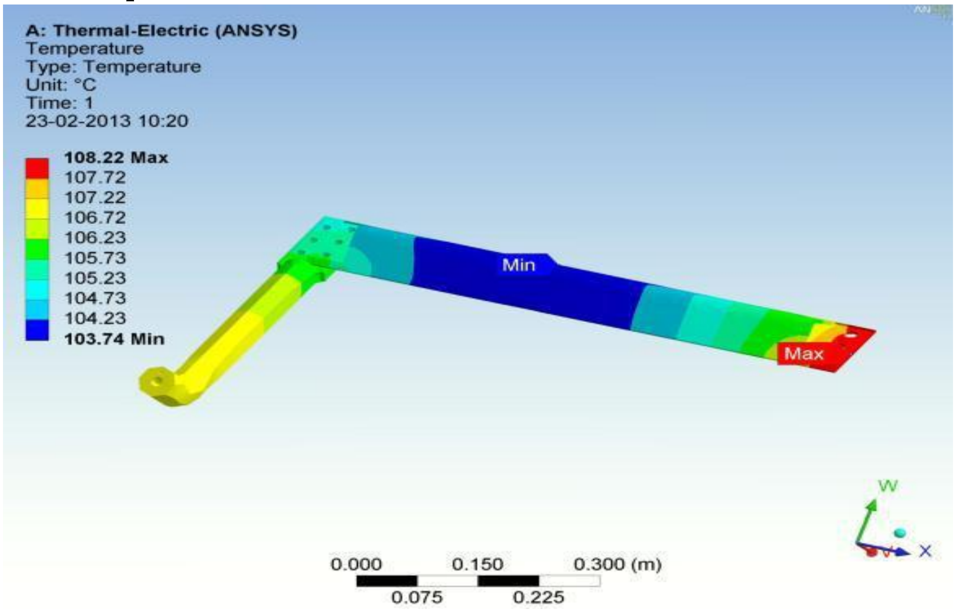

Figure: 3

Properties of Aluminium:

Table: 4

Density	2700 Kg/m^2
Coeff. of thermal expansion	10 $W/m^2/k$
Thermal conductivity	236 W/m/k
Specific heat	900 J/kg/k

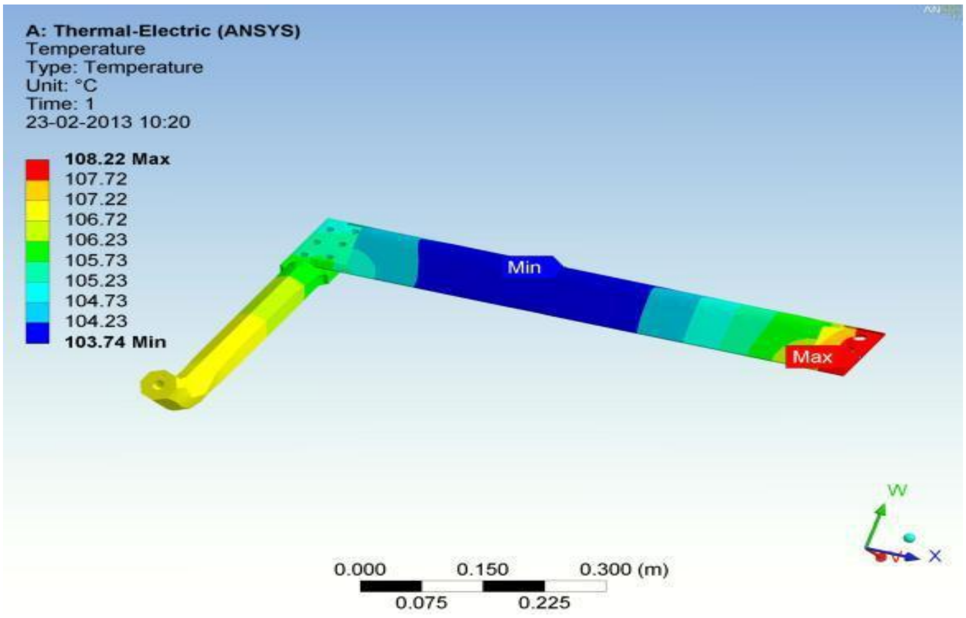

Figure: 4

Aluminium at 1500amp

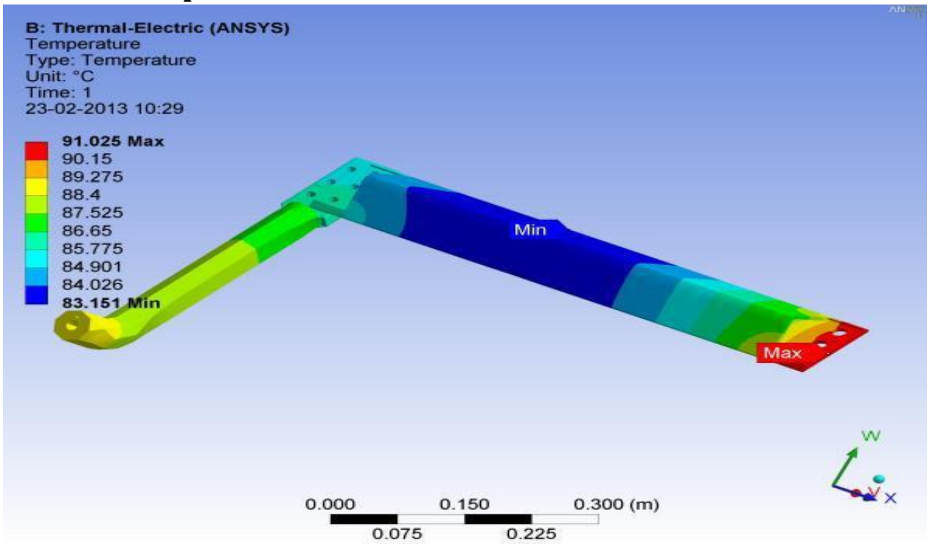

Figure: 5

For copper end temperature is 115^0 C and temperature at 2500 amp is 108.22 ^{0}C

Prediction of Temperature Rise for Higher Current Rating:

As we can see simulation results are approximately close to practical data we run out simulation for higher current rating and temperature rise observed

Aluminium at 2000amp

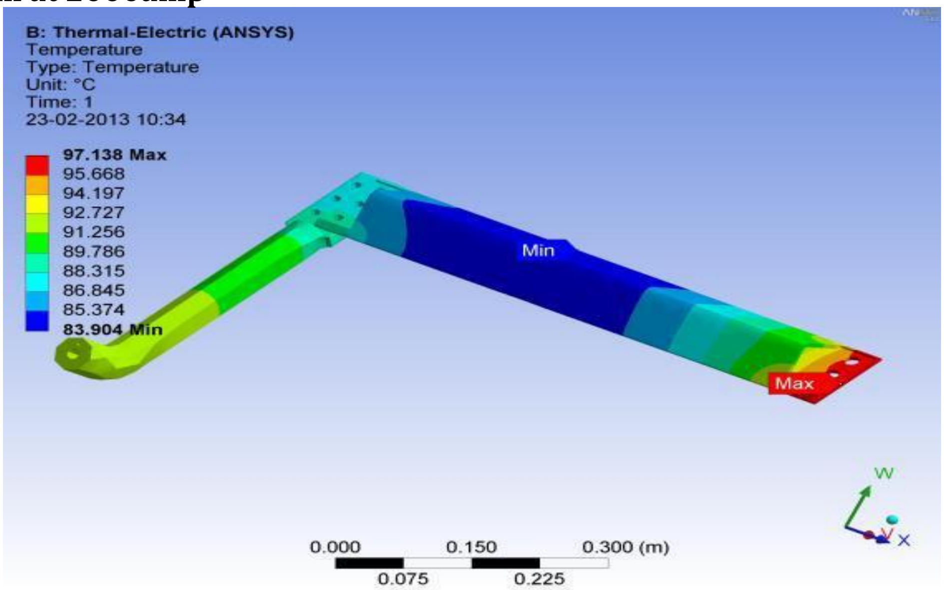

Figure: 6

For Aluminium end temperature is 105 C and temperature at 2000 amp is 97.13^{0}C

5. Conclusion:

Finite element method for analyzing the electro-thermal behaviour is important tool for thermal rating of switching devices. Verification of simulation results with real time practical data obtained from TRT test makes simulation results more reliable hence more accurate prediction of temperature rise for higher current rating. It reduces product development time as well as cost. It helps in very early phase of product development to identify failure conditions and help to prevent future unexpected pitfalls.

6. References:

1. Switchgear protection and Power Systems by Sunil S. Rao, ANSYS Manual, ANSYS 12, ANSYS Inc.
2. Thermal simulation of switch gearbyJ. Paulke, H. Weichert, Rockwell Automation AG
3. Research on Temperature Field of Switchboard Based on Finite Element Method by Zou Bin, uzhou University, IEEE Sep 2009
4. Simulations of the Heat Balance in Low-Voltage Switchgear by F. Barcikowski , and M. Lindmayer (ICEC 2000) Norra Latin, Stockholm City Conference Center, Stockholm, Sweden, 19.-23. June 2000.
5. Transient thermal analysis of fast switching devices by partially coupled FEM method by Ahmed Lakhsasi IEEE CCECE/CCGEI, Ottawa, May
6. Fundamentals of finite element analysis by David V. Hutton