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Prospect/Retrospect

Higher Ampacity Of Busbars

In the initial days, Power Control Centres (PCCs) were connected to the transformers and through feeders of the PCCs, various Motor Control Centres were being fed. This led to duplication of feeders, extensive cabling and higher costs. In LV switchgear, most of the power transformers used to be 1000kVA or 1600kVA. Thus, the maximum currents were of the order of 2000-2500A.

When PMCCs were introduced, larger transformers were connected directly to the Motor Control Centres through ACB incomers. Last decade has seen the transformer rating going up (upto 2500kVA) and thereby the current rating of the busbars also increasing. For a medium size industrial plant, busbars of 3500A current rating have become a normal requirement.

Earlier specifications used to specify ambient temperature as 40 deg. C. Later, it was also realised that the tropical conditions in our country may lead to an ambient of 45 deg.C. or even higher at a few places.

This awareness on the part of customers brought temperature rise limits on the busbars in switchboards. It was also realised that for paper bonded insulators, the insulating properties deteriorate rapidly at higher temperature, resulting in arcing fault in the busbar zone.

When low temperature rise and higher current ratings were specified, switchboard manufacturers started:

– Increasing the cross section of busbar conductors
– trying with different geometry of conductors for busbars.

Simultaneous study of different variables under stipulated conditions revealed that:

– ampacity of busbars is governed by:
  - material of busbars (aluminium/copper)
  - cross section of busbars
  - profile of the conductors
  - spacing between the conductors of same phase
  - total busbar zone volume
  - type of ventilation
– beyond a certain cross section, adding to the cross section of the conductor does not increase ampacity of the busbar at all.
– different profiles of conductors of same cross section give different ampacity under the same conditions.
– any profile, other than rectangle, poses difficulty in manufacturing, assembly and maintenance.
– if the busbar thickness is increased, its current carrying capacity doesn't increase proportionately. So, choosing a conductor of rectangular cross section, with minimum thickness, which is adequate for required mechanical strength provides the best alternative.
– above 1600A rating, ventilating louvers help in increasing ampacity of busbars.

Inductive reactance of the busbars results in higher temperature rise.

Even the conduction losses in switchboards have a cumulative effect. They result in higher busbar temperature, burdening the air-conditioning system. It also means loss of power for which the user has to pay. Thus, effective steps taken to reduce these conduction losses will not only save the user's money but it will also make the system eco-friendly!

In this issue of *L&T Current Trends,* we bring you the analysis of this inductive effect on the ampacity of busbars and a probable solution to achieve higher ampacity of the busbar.

Interleaved busbar system for a.c. applications
An effective solution for achieving higher ratings

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Temperature rise (TR) is an important consideration for busbar installations. As far as required ampacity of busbar system is below 1600 A, it can be conveniently achieved by using one or more conductors of suitable size and shape. The problem lies in designing an a.c. busbar system for higher ampacities. Test results show that increasing cross section beyond certain limits in a conventional manner (say by adding a conductor or increasing the thickness) gives marginal increasing in the ampacity. The reason is skin and proximity effects or in other words, inductive effects due to a.c. currents.

Direct current distribution over a cross section depends only on the resistance and hence current density is uniform irrespective of shape, size and arrangement of conductors. However, a.c. distribution is controlled more by inductive effects than by resistance. Effect of current in the conductor itself is known as skin effect. This causes the current to concentrate in the outer parts. Effect of current in the adjacent conductor is known as proximity effect. Inductive effects result in non uniform current distribution over a cross section (i.e. inefficient use of conducting material); consequently making busbars to run at a higher temperature.

Figure 1 gives current distribution pattern over round conductors in various configurations where each dot represents a unit quantity of current.

Why does non uniform distribution result into higher losses and thereby high temperature?

To understand this, take the case of a flat shaped conductor assumed to be comprising several smaller conductors of equal area in parallel, carrying total current of 10 A as shown in figure 2 on page 4. In the case of uniform distribution, watt loss works out to 20 W. For non uniform distribution, element-wise currents differ not only in

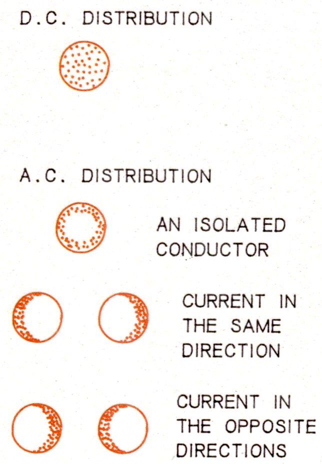


Figure 1

magnitude but also in phase angle (Note that arithmetic addition is 11.2 A). Watt loss in this case is 30.8 W. As watt loss is more, steady state temperature will be higher for the same value of current; or for the same steady state temperature, it will have lower apmacity.

The ratio of a.c. to d.c. watt loss is known as Rac/Rdc ratio. (Hereafter termed as 'ratio'). This indicates effective resistance (Rac) offered by a configuration in relation to the actual resistance (Rdc). Ideal (minimum) value of this ratio is 1 i.e. Rac = Rdc.

What is interleaving?

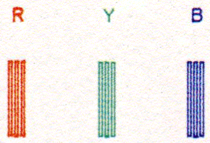
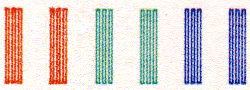
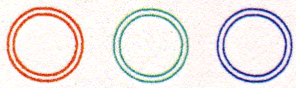
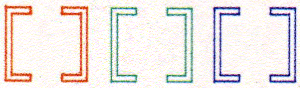
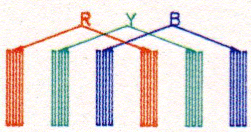
For increasing busbar system ampacity, conventionally one tends to add a conductor or a group of conductors adjacent to existing conductors / groups and ends up placing all conductors / groups together. (Refer to table 1, configuration 2) This results in widely non uniform current distribution due to skin effect and proximity effect. Proximity effect is dependent on the distance between conductors. Hence, this problem can be overcome by arranging individual conductors in specific geometries. Interleaving is one such arrangement. (Refer to configuration 5).

Interleaving means arranging conductors groups in the alternate fashion (R Y B R Y B). In the configuration 5, two groups of three conductors each per phase have been arranged in this fashion. One can go even beyond this and make three groups of two conductors each to increase the rating further.

Table 1 gives ratios for various configurations of three phase busbar systems with wide and moderate/close interphase spacings. One can note the difference between the ratios for wide spacings and close spacings for configurations 2, 3 & 4. Effective resistance (relative) is given in the last column.

Discussion on Table 1

(1) Effect of increase in busbar cross-section in a conventional manner: Configuration 2 is having double the cross-section as that of configuration 1. However, effective resistance for middle phase is more and so is the heat produced at same current. Thus, increasing aluminium. This is because for copper, inductive effects distort current more due to lower resistance. This reflects in the effective resistance (Rac) which is not lower in the same proportion as that of Rdc. Considering the fact that heating is proportional to the square of the current, rating with copper would be only 19% evident from ratios for wide spacings at which interphase proximity effects are negligible. However, for close spacings, configurations 3 and 4 are marginally better than configuration 2. These sections are also not desirable as processing on machines, making joints etc. is difficult.

	CONFIGURATION	C/S AREA in^2 / PH	Rac/Rdc ISOLATED PHASE (WIDE SPACINGS) R,Y,B	Rac/Rdc (AT 50 Hz) THREE PHASE SYSTEM MODERATE SPACINGS - CONFIG.1 CLOSE SPACINGS - CONFG.2 TO 5: R	Y (MIDDLE)	B	RESISTANCE Rdc * (RELATIVE)	EFFECTIVE RESISTANCE (MIDDLE PHASE) Rac * (RELATIVE)
1		4.5	1.27	1.27	1.34	1.27	2	2.68
2		9 Al Cu	1.54 –	1.85 2.34	2.71 3.54	1.77 2.25	1 0.55	2.71 1.95
3		9 Al	1.05	1.68	2.73	1.52	1	2.73
4		9 Al	1.1	1.57	2.54	1.45	1	2.54
5	INTERLEAVED SYSTEM 	9 Al Cu	–	1.32 1.54	1.31 1.61	1.34 1.56	1 0.55	1.31 0.86

- RESISTANCE VALUES ARE RELATIVE WITH THE BASE VALUE OF 9 SQ. IN. ALUMINIUM AS 1

Table 1

the cross-section has not given any benefits. Configuration 2 will carry more current only because more number of flats are available for dissipating the heat.

(2) Effect of changing the material from aluminium to copper: For configuration 2, copper is having higher ratio as compared to that of more. Thus, for large cross-sections, changing the material from aluminium to copper gives marginal increase in the ampacity at a very high cost.

(3) Use of Tubes/Channel section (configurations 3 & 4): These are often suggested for busbar systems as they are ideal shapes to counter skin effect. This is

(4) Interleaved System (configuration 5):
For same cross sectional area, interleaved configuration 5 enjoys much better rations than configurations 2, 3 & 4. This is due to substantial improvement in current distribution as proximity effects tend to cancel each other.

Comparing this with configuration

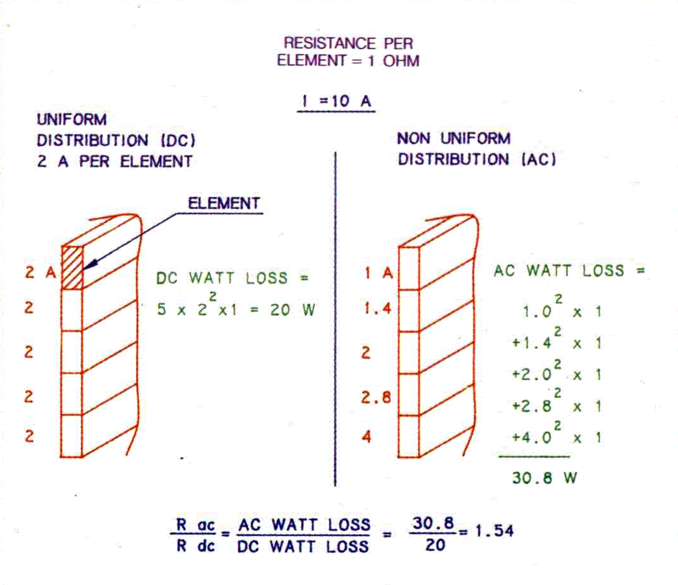


Figure 2

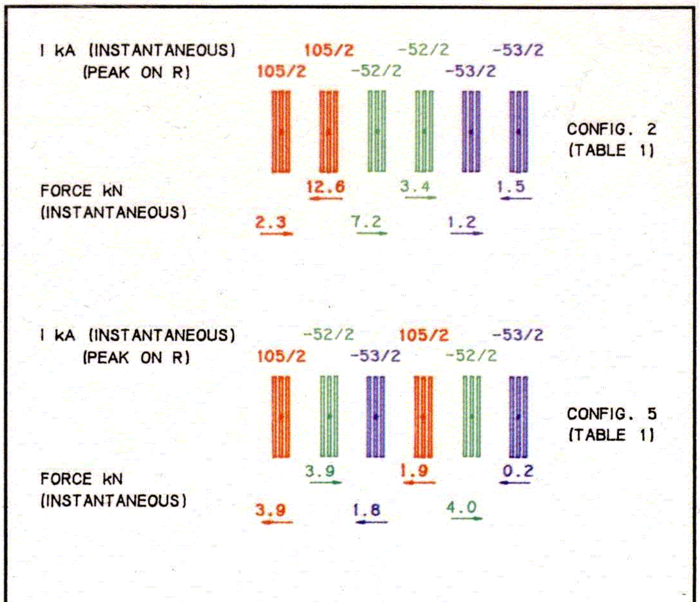


Figure 3

2, effective resistance for middle phase is less than half. Therefore, ampacity would be more by around 35 to 40% for aluminium and 40 to 45% for copper or in other words, the losses will be less in the same proportion.

One can also note that for interleaved system, ratios for all phases are uniform; while for other configurations, ratios for middle phase are much higher. Thus, ampacity is limited by TR on this phase even though outer phases run cooler.

Results of TR test

A test was carried out on a 2.5 metre long busduct (IP54) with configurations 2 & 5 with aluminium at 3150 A. Average rise for configuration 2 was 66°C and that for configuration 5 was 36°C.

Other advantages of interleaved system

(i) It offers lower and balanced impedance. This becomes important for long busducts where voltage drop is critical.

(ii) Figure 3 gives instantaneous (at the instant of 105 kA peak current in the R phase) values of short circuit current and force for configurations 2 & 5. For the interleaved arrangement, forces due to short circuit current are much lower. This enables redesign and reconsideration of the busbar support system. Also, it can enable the existing support system to withstand much higher fault levels.

Disadvantages of the interleaved system

(i) Phases see each other at greater number of places. This may increase size of busbar chamber.

(ii) Putting equalizers between groups is difficult. However equalizers are not required if each load is tapped from both packets.

(iii) For busduct applications, phase cross-over chamber may become essential to facilitate passing all bars (of a phase) through CTs.

Conclusion

Considering all pros and cons, optimum solution for reducing loss of energy and achieving high ampacity busbar system would be interleaving. As interleaved system needs less material and use of aluminium is possible for very high ratings, this system is better suited for Indian conditions.

ISO 9001 for L&T's Switchgear and Petrol Pumps

The switchgear and petrol pump - related operations of Larsen & Toubro Limited have been awarded ISO 9001 certificate by BVQI, London - one of the leading accreditation agencies in the world - following comprehensive audit of quality systems at the Company's factories at Powai, Madh and Ahmednagar as well as its marketing offices.

The ISO 9001 certification covers design, manufacture, marketing-installation and servicing of switchgear and controlgear products; switchboards; and petrol metering and dispensing units. The product range covered includes about 550 catalogued and price-listed standard products, motor and power control centres and various types of petrol pumps with mechanical and electronics register. L&T holds a leadership position in India for these products.

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