Low Voltage Distribution System Improving Its Efficiency

Anand J. Kurien

Larsen & Toubro Ltd., Switchgear Training Centre Ooty-Coonoor, Main Road Ketti-643243, T. N.

Abstract

The low voltage distribution system is the lifeline of any industry. Quite often its existence is taken for granted - till there is a breakdown. Its main job is to carry power to the point of use. Careful attention to it can avoid expensive downtime loss as well as give you considerable monetary savings. This paper looks at a typical low voltage distribution system & the steps we can take to make it more efficient & reliable. Two of the major issues addressed in this connection are Preventive maintenance - with special reference to better termination practices on lv.switchgear. Proper selection of switchgear on the basis of features especially to aid maintenance is also highlighted. The selection of low watt loss fuse links helps in reducing heat generation and use of power factor improvement reduces line loses. Harmonics - The addition of non-linear electronic loads in industrial plants has contributed to increase flow of harmonic currents. The presentation discuses briefly the causes, effects of harmonics and the role of third and fifth harmonic is particularly highlighted.

INTRODUCTION

Preventive maintenance aspects-Saving valuable downtime

Better termination Practices on Switchgear

The importance of proper termination

Any switchgear, by its very design, as a certain value of contact resistance. As a result of this, on passage, heat is generated within the switchgear. In order to keep the temperature within the specified limits, the switchgear designed to dissipate this heat to the surrounding atmosphere by radiation and by construction through connected busbars / cables. Hence in addition to the general understanding that busbars / cables are meant only for carrying current, it should be understood that they are also functional in carrying away the heat generated in the switchgear. Terminations by virtue of their contact resistance are also sources of heat. But in an electrical system, the heat generated at the terminations is less than that generated within the switchgear.

The importance of proper termination thus becomes apparent as it ensures that in many switching system, the terminations do not act as sources of heat but as heat sinks instead.

The typical thermal scan of a general switching arrangement with proper termination will thus assume the profile as shown in the above figure. Proper termination cables / links and switchgear must be insured at the time of installation; and periodic maintenance procedures must include regular inspection / tightening of these termination.

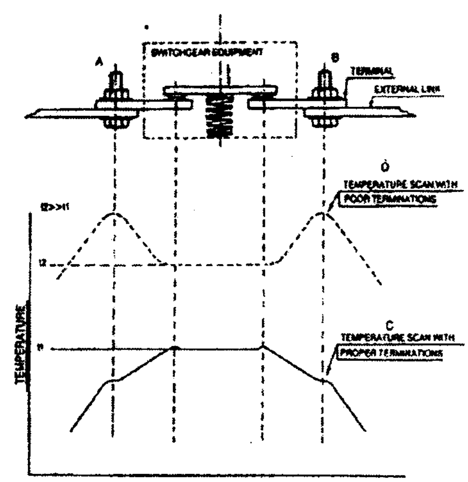

Fig. 1 : The low voltage distribution system improving its efficiency

Termination of Cables onto Switchgear

Cables can be terminated on to the terminals of switchgear either directly or through cable lugs. Precautions to be taken while terminating cables directly or through cable lugs onto switchgear terminals:

(a) Method of stripping insulation:

It must be ensured that the sharp edge used to remove insulation does not cut into the conductor. Never ring a conductor while stripping insulation. One way to avoid is to pencil or whittle the insulation. Another method is to skin the insulation back from the cut end of the conductor and then cut outwards. For small-sized wires, the insulation may be removed quickly and easily by a stripper (as long as it is ensured size of the notch in the stripper matches the size of the conductor).

(b) Another precautions to be taken in is that minimum length of the conductor should be bared beyond the termination point. Care should be taken, however, to ensure that no insulation is trapped at the termination point.

(c) Cables should be well supported and it should be ensured that they do not exert any undue pressure on switchgear terminals. To this end, cable glands should be provided at appropriate location. This will not only prevent breakage/ bending of terminal plate/terminal, but also in case soldered cable lugs joints, the cable will not drop of the lug if the solder softens.

(d) When bare Aluminium is exposed to atmosphere, a non-conducting layer is formed on the surface of the conductor.

Hence insulation from the cable should be removed only at the time of termination. Before termination. the conductor surface/wire strands should be cleaned with a hard wire brush and the surface should be covered with oxide inhibiting compound/grease.

Precautions to be taken for termination of cables/wires onto terminals of switchgear

(a) The extent of wire wrapping around the terminal screw and the method of doing so are critical.

(b) Correct mechanical pressure during termination should be applied on the conductor - Over tightening of clamping screw may sever the conductor while under tightening can cause overheating at the termination point. For proper tightening of terminals, the user should adhere as closely as possible to the manufacturer's recommendations on tightening torques. (Following are the examples for tightening torque).

These values apply to bolts with lengths in excess of 5 times the thread dia. For smaller length of bolts, the values are to be reduced by 10%.

For verification of application of correct torque, the termination procedure should be correct and for correct indication of torque, the situations should be avoided. A torque wrench should be used to verify the correct torque applied.

Termination of Cables through cable lugs

The Indian standard of PVC insulated cables permits considerable tolerance in the geometrical cross-section of the cables having the same nominal size. As a result there can be considerable clearance between the outer diameter of the conductor and the inner diameter of the cable lug. It is therefore very important to select the correct cable lug such that:

(a) The conductor is fully accommodated within the lug, and

(b) The lug has as close a fit as possible to the conductor.

Cable lugs can be fitted to the cable conductors by either

(a) Soldering

(b) Crimping or compression jointing

Crimping is preferred to soldering as the latter has the following disadvantages:

- A good soldered joint with Aluminium conductors requires skilled technical expertise.
- Useless care is taken, it is difficult to avoid formation of film of non-conducting Aluminium oxide thus preventing intimate metal to metal contact.
- Soldered joints are not reliable as they tend to become mechanically weak at about 180°C-a temperature possibly attained under short circuit conditions.

Crimping/ compression jointing

For crimping of 10.15 and 25mm^2 cables a single crimp is sufficient. So the lug should be positioned to have the crimp in the middle of the barrel. For cable size 36mm^2 and above, two / three crimps are recommended. The lug should be positioned so as to have the first crimp on the straight position of the barrel towards the pan handle (the crimp should not be made on the curved shoulder between the pan handle and the barrel of the lug). The second crimp should be made inwards along the barrel about 3-

Thread	M5	M6	M8	M10	M12	M14	M16	M18	M20
Torque Kgf-m	0.22	0.38	1.10	2.10	3.55	5.30	7.75	10.5	14.2

4mm away from the first crimp.

The following precautions should be taken for compression jointing/crimping:

(a) Normal length of insulation to be stripped from the cable/wire should be equal to barrel length plus 1 to 3mm.

(b) Crimping should be carried out as per the recommendation of the cable lug/crimping tool manufacturer. For correct crimped joints proper die and tool is essential to ensure matching between conductor and lug as well as between lug and die.

(c) It is advisable to fill the lug barrel with inhibiting compound. In addition, the compound should also be applied on the exposed cable strands.

Termination through links/busbars

While terminating links or busbars onto the terminals of any switchgear the following points should be considered:

(a) The conductivity of the aluminium or copper links / busbar should be high. Preferably electrolytic grade Copper of 99.9% IACS and Aluminium of 55% IACS should be used. (It may be noted that the Aluminium flats commonly available in the market have a conductivity of only 53% IACS). If lower conductivity material is used, the cross sectional area of the conductor should be suitably increased to avoid problems of overheating.

For example 90mm^2 electrolytic grade copper of 99.9% IACS as approximately the same current carrying capacity 150mm^2 copper of 60% IACS.

(b) The current carrying capacity of a conductor can be increased for a given temperature rise by painting the conductors with a flat matt-finish black paint of nonmetallic pigment. This improves the thermal emissivity of the conductor.

(c) When busbars/links are connected in parallel, some gap should be maintained between parallel busbars/links to improve heat dissipation. This gap should be equal to the thickness of the busbar/link or 10mm whichever is higher.

(d) Before connecting Alunimium busbars/links to switchgear terminals, the busbar/ links should be cleaned with a hard wire brush and then contact grease should be applied. Tinning of busbars also ensures inhibition of oxide formation.

(e) The conducting link/busbars should have only the required number of holes for joints. The size of holes should be slightly larger than that of the connecting stud/bolt. The fairy common situation of the old being significantly larger than the stud / bolt resulting in the bolt head pushing the washer through the hole, must be avoided. Again while joining, the number of contact surfaces in serious should be kept to the minimum.

(f) While installing busbar/links, care should be taken to ensure accurate positioning of fixing holes. Termination that forcibly take care of misalignment / offset lead to undue pressure being exerted on the terminals and the insulated terminal plates, resulting in their breakage. Also, even if there is no offset, busbar/links should be adequately supported along their length so that they do not exert any undue pressure on switchgear terminals under normal or short circuit conditions.

(g) For proper terminations between link and switchgear terminals, the contact area must be adequate. The following situations should also be avoided as they lead to creation of heat sources at the point of termination:

• Point contact arising out of improper positioning of links with switchgear terminals.

• Gaps between busbar/links and terminals being the remedied by connecting bolt/stud. In such cases the bolt will carry the load current. Normally these bolts/studs are made MS and hence are not designed to carry currents.

(h) Adequate clearance between busbars/links at terminals should be maintained (IS: 4232 may be referred to for guidelines).

Problems of jointing dissimilar metals

Another important consideration is the placement of dissimilar metals in contact with each other, e.g. Aluminium conductors in contact with a terminal made of Copper or Copper based alloys. In fact this problem is most serious in the case of Aluminium to Copper contacts. In case of Aluminium to Copper joints exposed to moist, saline or polluted atmosphere, the Aluminium part commences corroding first as Aluminium is more anodic to Copper. However, with the formation of sufficient amount of Aluminium oxide, Copper becomes anodic to the Aluminium oxide layer and starts corroding also. This type of corrosion takes quite some time, but its effects are detrimental to the joint. As this corrosion leads to increase in contact resistance, the overheating at the joint can cause insulation failure.

The following methods/measures can be considered

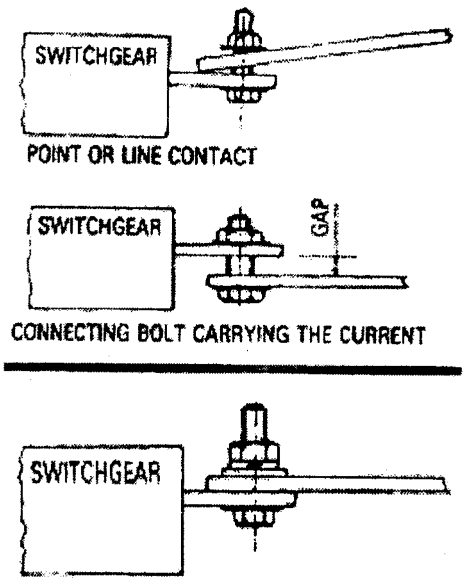

Fig. 2 : Face to face contact

to prevent such galvanic corrosion:

(a) Tin plating of terminals

(b) Use of productive compounds to prevent in gress of moisture into the joint.

(c) Bimetallic bonded Aluminium-copper connectors (also known as Copal Washers) inserted between Aluminium cable and copper terminal. This will prevent galvanic corrosion but initially, insertion of the washer may increase contact resistance. Hence care should be taken that by using these washers, the temperature rise of the termination does not exceed the specified limits.

(d) Use of lugs which has copper termination surface friction-welded onto the Aluminium lugs.

Methods to identify quality of termination

(a) **Quality of insulation:** Inspection of quality of insulation under the terminals gives an indication. Whether insulation has failed due to high temperature arising out of improper termination.

If the insulation is made of phenol formaldehyde (bakelite) the effected surface will have a dull finish (under healthy conditions, pf moulding will have shiny finish). Also there will be blisters on the effected surface. If the insulator is made of SMC? DMC the surface may disintegrate and white fibers may be seen.

(b) To verify if proper contact is made between switchgear terminals and internal link, any of these two methods may be adopted:

If feeler gauge of 0.05mm is available, try and insert this in between the terminal and external link. If this is possible connections are not proper. (If feeler gauges are not available even thin paper may be used). However this is not a positive test since it must be noted that if the feeler gauge cannot pass through the space between terminals and links, it does not mean that the pressure is correct. Place a carbon paper on a tissue paper with the dark side of the carbon paper facing the tissue paper. Make a hole in these two papers approximately the size of the connecting bolt of the terminal. Place the two papers between the terminal and link with a connecting bowl passing through the hole made on the two papers.

Tighten the bolt to the required torque. Unscrew the bolt & remove the two papers. The tissue paper will indicate the area of contact made between terminal and link. If the pattern of the tissue paper is uniformly dark, the connection is proper.

Table 1: Typical mV Drop Values

Joints	Test Current	mV Drop Upper Limit	mV laboratory Conditions for Good Terminal Joints
Link to Terminal	100 A ac / dc	2.5 mV	0.5 to 1.1 mV
Cable Lug to Terminal Upto 50 Amp	050 A ac / dc	8.0 mV	1.0 to 2.0 mV
Cable Lug to Terminal Upto 50 to 100 Amp	050 A ac / dc	5.0 mV	2.0 mV
Cable Lug to Terminal Beyond 100 Amp	100 A ac / dc	2.5 mV	0.5 to 1.5 Mv
Cable to Cable Lug	At Rated Currents	5.0 mV	2.0 to 3.0 mV

One of the most important aspects is the proper termination practice. With the help of a case we see how a small thing like a loose nut on the termination of a typical switchgear unit can cause immense damage. Simple practical steps can be taken to avoid this breakdown situation. The millivolt test is the most reliable way to check whether the electrical termination is proper. A millivolt drop of 5-8mv is ideal.

Some maintenance features for selection of Switchgear

While selecting various LV. switchgear care can be taken to make the maintenance easier by looking out for these features in low voltage switchgear. Some of these features have been provided by leading switchgear manufacturers after years of experience in studying switchgear usage in India. For example;

- Terminals are designed for terminating aluminum cables and flats. These are widely used in India-unlike copper cables & flats abroad.

For eg. According to IS 13947-Part I the specification for Aluminium link sizes are given as in the table below. Care should be taken to see that sufficient terminal width is available on switchgear for termination of Aluminium links.

- The ambients defined by Indian Standards are on an average 10°C higher than ambients defined by IEC.
- Finger proof terminals on contactors, shrouding of terminals, improve safety to persons and reduce chances of flashover between terminals.
- Air circuit breakers should have a fourth maintenance position draw out (in addition to service, test, isolated) to facilitate maintenance with minimum of downtime.

Table 2

Current * (A)	Aluminium Bars as per 1513947 Part 2	
	No. of Runs	Dimensions (mm)
400-500	2	32 x 8
500-630	2	40 x 8
630-800	2	50 x 8
800-1000	2	50 x 10
1000-1250	2	63 x 12
1250-1600	4	50 x 8
1600-2000	3	100 x 10
2000-2500	4	100 x 10
2500-3150	4	150 x 10

- Enclosing of contacts prevents exposure to atmosphere.
- At the same time it should be easy to inspect the contacts & replace if necessary.
- Proper settings of relays & selection of fuse links is another important aspect to be stressed. This will ensure that you don't have instances of nuisance tripping while at the same time ensuring reliable protection of expensive equipment.

Saving your energy bills

A simple step like use of low watt HRC fuse links of reputed makes in fuse can lead to savings of as much as 40W in every fuse switch unit when compared to ordinary fuse links. The lesser amount of heat generated improves the life of insulation. Switching off loads like heaters, lights, air-conditioners when not required is another neglected area distribution system where major savings can be made in your energy, bills. Use of time switches, which can be programmed to switch on ON/OFF of loads at preset time, can eliminate the human forgetfulness element in such instances.

The average power factor in an industry is around 0.8pf. Large savings in the energy bills can be achieved by utilizing static capacitors for improving the power factor. with the use of microprocessor-based relays automatic pf correction is possible to achieve pf close to 1.00, Other advantages include

- reducing heat loss
- lower ampere rating of cables
- reduced rating of transformers & other switchgear equipment
- saving in energy bills - due to no penalties, benefits from incentives.

The payback period of installing power factor correction capacitors can be as low as 6 months in some installations.

Harmonics

What are harmonics

Electrical loads can be classified as linear and non-linear loads. A linear load is one, which draws a sinusoidal current when subjected to sinusoidal voltage. The current wave may or may not have a phase difference with respect to the voltage. A pure resistance, inductance or capacitance or any combination of these forms a linear load. On the contrary a non-linear load is one, which draws non-

Table 3 The following tables gives the ill effects of Harmonics on different equipments.

Equipment	Nature of ill effect
Motor	Over heating, production of pulsating torque.
Transformer	Over heating, noise and insulation failure
Switchgear and Cables	Increased losses due to skin effect followed by over heating
Capacitors	Severe overloading followed by overheating
Protective Relays	Unreliable operation and nuisance tripping
Power electronic equipments	Mis-firing of thyristor and failure of semiconductor devices.
Control & Instrumentation Electronic equipments	Erratic operation followed by nuisance tripping and breakdown
Communication equipments	Interference and noise

sinusoidal or pulsating current when subjected to sinusoidal voltage.

Any non-sinusoidal current can be mathematically resolved into a series of sinusoidal components (Fourier series). The first component is called as fundamental and the remaining components whose frequencies are integral multiplies of the fundamental frequency are known as harmonics. If the fundamental frequency is 50Hz, then 2nd harmonic will have a frequency of 100Hz and the 3rd will have 150Hz and so on.

Sources of harmonics

Following are some of the non-linear loads which generates harmonics:

- Static Power Converters and Rectifiers, which are used in UPS, Battery chargers, etc. Furnaces
- Power Electronics for motor controls (AC / DC Drives).
- Computers.
- Television receivers.
- Saturated Transformers.
- Fluorescent Lighting.
- Telecommunication equipments.

The major effects of harmonics are :-

High Neutral Currents

Equipment having Switched Mode Power Supplies (SMPS) like personal computers, Tvs are non linear load which generate triplen harmonics. These are odd number harmonics of multiple 3 ie. Third, ninth, fifteenth etc. They are zero sequence in nature and hence add up in the neutral. The current in the neutral conductor will increase causing overheating, breakage of neutral conductor and resultant failure of lighting and electronic loads. This is of particular significance when – core cables are used. The solution to this problem is to

1. oversize the neutral

II. reducing the triple in harmonics by use of active harmonic filters. With the increasing use of single-phase SMPS loads it is advisable not to use – core cables.

While selecting 4 poles Iv switchgear it is better to ensure that the neutral has 100% rating. Circuit breakers with 200% rated neutral are available for areas where high amount of triplen harmonics are present.

Effect of fifth harmonics

Fifth and seventh harmonic currents are present when a six-pulse rectifier is used in the system. The fifth harmonic being negative sequence in nature causes a pulsating torque in motors. This affects the output and especially in a paper industry, can effect paper quality, lead to expensive downtime due to interruption in process. Harmonics in general also contributes to a 5% reduction in motor efficiency. The solution lies in the use of detuned filters, detuned filters + active harmonic filters or active harmonic filters. The analysis and study of these filters - their selection, characteristics etc. are beyond the scope of this presentation. A proper system study has to be done to determine the percentage of harmonic currents & suitable solutions like filters can be adopted to reduce downtime, improve product quality & increase efficiency of the distribution system.