22kV Cable Termination Failure at Switchgears and Transformers - A Common Cause of Voltage Dip in Singapore

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Introduction

A common cause of voltage dip in Singapore is due to the premature failure of 22kV cable termination at customers transformers and switchgears. Such premature failures are mainly due to either bad workmanship or incorrect application of the cable termination materials or in some cases due to both factors. At the 22kV voltage level, there are broadly three types of cable terminations for switchgears and transformers. They are heat shrink type, cold shrink type and pre-moulded type. In Singapore, the heat shrink type is the most common and this article will discuss the premature failures of cable termination of the heat shrink type.

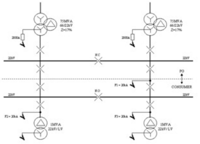

Figure 1

Voltage Dip

Figure 1 illustrates a typical connection between a 22kV customer and PowerGrid. Fault F1 is mainly at the 22kV cable termination of the customer incoming switchgear. Fault F2 is either at the 22kV cable termination of the customer outgoing switchgear or at the 22kV cable termination of the transformer cable box. Most faults are phase to earth and because of the confined space in the transformer cable box and switchgear, the earth fault will invariably lead to a three- phase fault. The magnitude of the 22kV three phase fault current will be largely determined by the impedance of the PowerGrid 66/22kV transformer. The impedance of the 22kV cable between PowerGrid and the customer is not large enough to significantly reduce the magnitude of the three phase fault. For various lengths of the 22kV, 3C/300mm2 XLPE cable, the reduction in three phase fault levels of 25kA is given as follows [1]:-

Length (meters)	Fault in kA
0	25.0
50	24.7
100	24.4
200	23.9
300	23.4
400	22.9

Therefore a fault of F1 and F2 is almost equivalent to a three-phase fault at the terminal of the PowerGrid 66/22kV transformer and is almost independent of cable length and impedance of customers transformers. Hence a customer with a small 1MVA, 22kV/400 Volts transformer can cause a voltage dip of similar magnitude as another customer with a large 20MVA, 22/6.6kV transformer.

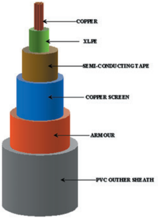

Figure 2

Cable Termination

An understanding of the causes for the premature failure of heat shrink cable terminations will need a basic knowledge of the construction of cables. Figure 2 illustrates the various layers of a common 22kV XLPE insulation cable. The copper screen and the semi-conducting screen are the most important layers with respect to the heat shrink cable termination.

The copper screen is connected to earth and therefore safe to touch. The earthed copper screen will evenly distribute the lines of electric field over the circumference of the XLPE insulation. Figure 3 illustrates the effect of the copper screen on the lines of electric field [2]. The absence of such a earthed copper screen will lead to localized areas of high stress due to the uneven distribution of the lines of electric field.

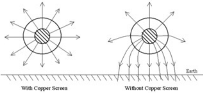

Figure 3: Lines of electric field

The semi-conducting screen, situated between the XLPE insulation and copper screen, will provide a more gradual transition between the insulating property of the XLPE and the conducting property of the copper screen. When the cable is stripped of its semi-conducting screen and the copper screen, the lines of electric field will concentrate over the small area at the interface of the semi-conducting screen and the XLPE insulation.

Something must be done to reduce the dangerous effect of the high concentration of electric field over such a small area. The solution is to spread the lines of electric field over a much larger area of the XLPE insulation. This is achieved by shrinking over the cable a stress control tube, an important component of the heat shrink cable termination. The lines of electric field will be distributed over the entire length of the stress control tube, which will be a much larger area as compared to the small area at the interface of the XLPE insulation and semi-conducting screen. The length of the stress control tube is dependent on the operating voltage of the cable.

TABLE 1 : GUIDELINE FROM SUCOFIT

	Length of stress control tube/mm	
Operating Voltage/kV	Single Core Cable	Multi Core Cable
22	190	260
11	130	190
6.6	100	150

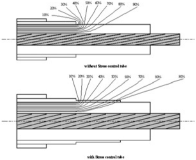

Figure 4: Lines of electric field

Figure 4 illustrates the difference in the lines of electric field for a cable with and without the stress control tube [3]. The use of incorrect length of stress control rube is one of the common cause of premature failure of cable termination.

Another common cause is the absence of measures to eliminate air pockets at the interface of the XLPE insulation and semi-conducting screen. If the stress control tube is applied over the interface of the XLPE insulation and semi-conducting screen, there will be pockets of air trapped inside the stress control tube. Such air pockets will lead to partial discharge when the cable is energized with normal operating voltage. The air pockets must be eliminated to prevent premature failure of the cable termination. A common technique is to use mastic tape over the interface of the XLPE insulation and semi-conducting screen. The stress control tube is then slipped over the interface and heat is applied. Under the application of heat, the mastic tape will greatly expand to fill up all the air pockets. Partial discharge due to such air pockets at the interface will be eliminated.

Case study 1

A petrochemical plant in Jurong Island had a failure of the 22kV cable termination at the 22kV switchgear. The pressure relief vents of the switchgear opened and this prevented the back cover of the switchgear from been blown off. A circular puncture of 10mm was found at the interface of the XLPE insulation and semi-conducting screen. The puncture went through the entire thickness of the XLPE insulation and exposed the copper conductor beneath. Investigation revealed that the stress control tube consisted of two over-lapping sections of stress control tube whose total length added up to 260mm. However as the length of first section of the overlapping stress control tube was only 120m, the cable termination was more

suitable for 6.6kV operating voltage. An inspection of the other 22kV cable termination revealed similar serious defects. The XLPE insulation was severely pitted and had turned powdery at the interface of the XLPE insulation and semi-conducting screen. The incidence illustrates the danger when the stress control tube is not of sufficient length. The failure of the cable termination occurred after 15 years of operation.

Case study 2

Another petrochemical plant in Jurong Island had a failure of the 22kV cable termination at the cable box of a 2MVA, 22kV/400V transformer. The metal cover of the cable box was completely blown off and some of the welded bolts of the cable box was found 10 metres away. A circular puncture of 15mm diameter was found at the interface of the XLPE insulation and semi-conducting screen. The puncture went through the entire thickness of the XLPE insulation and exposed the copper conductor beneath. Figure 5 is a picture of the damage. Investigation revealed the following:-

Figure 5: Circular puncture at interface of XLPE insulation

- Deep knife cuts at the interface of the XLPE insulation and semi-conducting screen were noticed. This was due to the bad job to remove the semi-conducting screen using a knife.
- No mastic tape was used to eliminate the partial discharge of the air voids at the interface of the XLPE insulation and semi-conducting screen.
- The components of the cable termination, like the stress control tube, anti tracking tube and breakout boot, were a mixture from different vendors.
- The length of stress control tube was only 190mm and it was not suitable for the 22kV three core cable.

All of the above caused the premature failure of the cable termination within 6 months of operation.

Case study 3

A plant in Jurong was found having audible discharge noise at the back section of the 22kV switchgear. Partial discharge monitoring revealed bad discharges at the area of the stress control tube of both the red phase and yellow phase cable terminations.

Figure 6: Discharge mark at cable termination

The discharge was because of insufficient air clearance between the two stress control tube. Figure 6 is a picture of the discharge. The area near the stress control tube is not at zero potential and there must be sufficient air clearance between the two stress control tube of different phases. The problem was caused by the use of 5 numbers of 3 core 22kV cables for the 50MVA load. The large number of the crossings of the cable core made it difficult to achieve the required air clearance between stress control tubes from different phases. The use of single core cable will be a better choice, and will completely eliminate all the crossings of the cables. The discharge occurred after 10 years of operation.

Recommendations

- In the three case studies, the cable termination was done by licensed cable jointers without any professional responsibility. Hence it is necessary for the client, consultant and contractors to be more stringent in the selection of licensed cable jointers.
- The client and contractor should directly purchase the material for the cable termination, rather than leaving this important task to the licensed cable jointer. This will eliminate the temptation to save material cost by mixing components from different vendors.
- In applications where more than one core of cable is required per phase, it is prudent to use single core cables as compared to multi-core cables. The use of single core cables will totally eliminate crossing of cables from different phases.
- The length of the stress control tube must be suitable for the operating voltage of the cable termination. For the existing electrical installations, the length of the stress control tube can be easily measured by visual location of the start and end sections of the stress control tube. In any shutdown maintenance, such measurements is strongly recommended. I have found many 22kV electrical installations with 190mm length stress control tube used in the common 22kV 3 core cables. The 190mm length stress control tube is more suitable for 11kV operating voltage.
- The absence of mastic tape to eliminate partial discharge due to the air pockets at the interface of the XLPE insulation and semi conducting screen is easily evident by visual inspection. There will be visible bulging at the interface because of the expansion of the mastic tape to fill up the air void. Such visual inspection is strongly recommended during any shutdown maintenance.

References

[1] Using ETAP TM Software from USA to calculate the fault current

[2] Page 371 of Power and Communication Cables by R. Bartnikas.

[3] Page 256 of Power and Communication Cables by R. Bartnikas.