Condition Monitoring of Power Cables






by Ir. Mohd Raffi bin Samsudin, Dr Ir. Ahmad Basri Abdul Ghani, Ir. Huzaini Shafe Abd. Halim, Ir. Radzlan Hisham, Ir. Zairul Aida Abu Zarim, and En. Wan Zakaria Wan Kamarudin

INTRODUCTION

Polymeric power cables are widely used in the power transmission network. The use of these types of cables is increasing worldwide due to their higher performance as well as environmental concerns. The most popular type of polymeric power cable is the cross-linked poly-ethylene (XLPE). The XLPE cable is the successor of the paper insulated lead covered (PILC) cables.

The laying of power cables is very expensive and it involves approval from many local authorities. Thus it is very important to ensure that the assets operate reliably over its lifespan. A cable, which has been laid, will undergo pre-commissioning tests to identify and mitigate any form of manufacturing or installation defects. Once the cable has been energised, the insulation will age, and in addition, the presence of abnormal stresses such as thermal, mechanical and electrical (e.g. lighting and switching), above its design stresses, will further expedite the degradation of the insulation.

The most common causes of power cable failures are third-party digging, overheating, poor installation of accessories, moisture ingress and cable manufacturing defects. Damage caused by third-party digging can be prevented through the installation of cable markers along the cable routes, so that any person at work in the locality will be aware of the presence of the power cable underneath. In addition, law enforcement by the local authority such as the requirement to perform the utility mapping within the proposed work area for digging or piling work will help minimise accidental damage to the power cables.

On the other hand, the developing fault of overheating, poor installation of accessories, moisture defects and manufacturing defects can be identified by using proper condition monitoring techniques and the output data can be used to evaluate and assess the health of the power cable.

CONDITION MONITORING OF POWER CABLES

The condition monitoring of a power cable is very important because it will enable the utility to carry out mitigation action before it breaks down. The common techniques for condition monitoring of power cables are Visual Inspection, Infrared Thermography, Ultrasound, Insulation Resistance, Dielectric Dissipation Factor and Partial Discharge. In addition, other factors such as the age of the cable, operation and maintenance history would also provide additional information on the health of the power cable.

1. Visual Inspection

The visual inspection of XLPE power cables is more focused on the termination at the transformers and switchgears. This is performed in order to check for the signs of dust accumulation, surface tracking and insulation degradation.

2. Infrared Thermography

Infrared thermography is performed in order to check for the signs of overheating at the cable termination. A loose termination will have a higher contact resistance which will eventually cause a higher resistive loss at the termination. The localised hotspots will lead to accelerated degradation of the insulating material of the power cable. In addition, a degraded insulation which has higher losses can be detected by this method.

The difference between the measured temperature of a termination with the ambient temperature or the adjacent termination is used to decide on the severity of the hotspot.

3. Ultrasound

Ultrasound detection can be used to detect the "noise" in the breaker compartment as well as the cable termination compartment. It provides a safe measurement distance without the direct exposure to the live parts. The detected noise is the symptom of developing fault such as corona, tracking, arcing and mechanical looseness. The level of noise and the frequency of occurrence are used to determine the severity of fault.

4. Insulation Resistance

Insulation Resistance testing is one of the most traditional testing techniques for power cables. It is performed by applying a DC voltage source through the cable insulation. The applied voltage may vary based on the voltage rating of the cable. The insulation resistance is the ratio of the applied voltage to the residual current through the insulation. For XLPE cables, the ratio between the resistance at 1 minute and 0.5 minute is used to assess the condition of the cable. This ratio is known as Dielectric Absorption Ratio (DAR).

5. Dielectric Dissipation Factor

The dielectric dissipation test is done to assess the condition of the XLPE. A degraded or contaminated XLPE will have a higher loss factor, and thus, it can be revealed through this test. The insulation integrity of the XLPE cable is influenced by the presence of moisture and/or water tree as well as aging. Figure 1 shows the typical water tree in the XLPE cable.

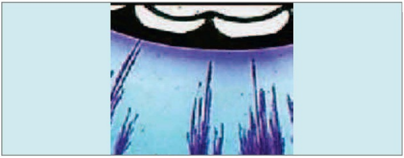

Figure 1: Typical Water Tree in Power Cables

6. Partial Discharge

Partial discharge in power cables may happen due to a few reasons such as sharp edges, voids and embedded metal. Partial discharges in power cables are similar to cancer in the human body, where earlier treatment can actually save the life. A partial discharge source in power cable can further deteriorate the insulation which will eventually develop into arcing. The arc will further damage the insulation and finally, it will cause the system to trip.

The level of partial discharge is measured in pC (pico-Coulumb) and Table 1 summarises the PD level and the proposed action for XLPE cable. Meanwhile, Table 2 summarises the PD level and condition indicators for XLPE termination.

Table 1: PD Level and Proposed Action for XLPE Cables

PD Level (pC)	Proposed Action
0-250	Discharge within acceptable limit.
250-350	Some concern, monitoring recommended.
350-500	Some concern, regular monitoring recommended.
>500	*Major concern, repair of replace.*

TABLE 2: PD Level and Condition Indicators for XLPE Terminations

PD Level (pC)	Condition
0-500	Good
500-2500	Fair
>2500	Bad

7. Case Study

An underground power cable segment was selected from Site A, for the condition monitoring purpose. The above-mentioned methodology was used to assess the condition of the cable. The insulation resistance and partial discharge tests were carried out to assess the condition of the cables. The tests revealed that some partial discharge activities have occurred at the cable joints. The post-mortem and repair work were performed. Table 3 summarises the PD level and DAR readings before and after the repair.

Table 3: PD Level and DAR Readings Before and After The Repair

	Red		Yellow		Blue	
	Before	After	Before	After	Before	After
Ground Noise [pC]	142	3	162	27	148	51
PDIV [kV RMS]	5.1	5.7	6.4	8.2	4.5	6.3
PDEV [kV RMS]	5.6	5.6	5.6	-	5.9	8.2
PD max. Uo [pC]	17200	234	107	0	580	95
No. of PD events Uo [N]	34	2	4	0	27	1
PD max. 1.3Uo [pC]	**42100**	**590**	**145**	**74**	**3050**	**110**
No. of PD events 1.3 Uo [N]	24	13	8	1	17	2
Dielectric Absorption Ratio (DAR)	**1.32**	**1.58**	**1.15**	**1.23**	**2.2**	**1.12**

The joints were retrieved from site and a post-mortem was performed. Figure 2, Figure 3 and Figure 4 show some developing faults in the joints. The PD was mainly observed at the ferrule which caused insulation burning.

After the repair work was done, the PD was repeated. The amount of PD was reduced significantly at the same location. This concludes that the condition assessment performed at Site A had managed to save the utility from a breakdown loss.

Figure 2: Burn mark at the ferrule (R-phase)

Figure 3: Burn mark at the insulation (Y-phase).

Figure 4: Burn mark at the insulation (B-phase).

CONCLUSION

Proactive power cable management is necessary to prolong the lifespan of the cable, as the test results can be used to generate the condition index of each cable. The condition index of a power cable will enable better planning on the cable loading and replacement regime. The information obtained from the condition monitoring methodology can also be used for better maintenance planning and management, hence reducing power outages and ensuring the continuity of supply. In addition, the knowledge of the health of the power cable is very crucial, so that a quick counter-measure can be taken against any overload condition.