INTRODUCTION

MV underground cable failures have been contributing to some 60% of annualized SAIDI for a number of years. Bulk of the reliability issues originated from MV underground cable joint failures. Special programs focused on skilled development of jointer and VLF Testing of cables were implemented over the last few years. Despite some early success, this approach is increasingly seen as being not sustainable as the fundamental issue of cable joint reliability and subsequent choice of cable joint technology is still unresolved. The choice of joint technology for MV underground cables has been a subject of much debate in the local industry in the midst of the growing evidence that the existing cable joint design is not performing well enough under the local operating environment. The approach towards seeking the long-term solution to the choice of cable joint technology is to conduct special performance-based laboratory testing. The methodology and tests are so designed as to expose the selected cable joints to extreme operational conditions and environment. Identified cable joint technologies and respective brands will later be further exposed to “extended field trials” before any standardization decision is made. This paper discusses the approach, methodologies and initiative in managing improvement effort of MV underground cable joint.

MV UNDERGROUND CABLE JOINT PERFORMANCE

More than 50% of the breakdown is due to cable joint failures. Almost 50% of these failures are due to water ingress into the joints. Most of the failure cases occur at the joints that were installed at high water table area.

<table>
<thead>
<tr>
<th>Year</th>
<th>No : of MV underground cable faults</th>
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<tbody>
<tr>
<td>2000</td>
<td>8232</td>
</tr>
<tr>
<td>2001</td>
<td>7035</td>
</tr>
<tr>
<td>2002</td>
<td>5997</td>
</tr>
<tr>
<td>2003</td>
<td>6177</td>
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Table 1: MV underground cable failure statistics

Shortcomings in water blocking systems on certain joints installed in wet areas and other workmanship related causes are major concerns.

11kV UNDERGROUND CABLE JOINTS

Application of cable joint technologies in TNB

The bitumen compound filled joints was used since the early days when PILC underground cables were the type of cable. Despite its reliability due to its inherent water tight design, bitumen compound filled joints requires lengthy installation period i.e 6 to 8 hours. As early as late 80s, heat shrink joint technology was slowly introduced and the driving factors leading to the migration to heat shrinkable are the faster installation, supposed lesser skill requirement and the introduction of XLPE cables. At some point, resin filled joint technology was also tested but not adopted due to amongst others its comparative high cost, high dependence on quality of resin and shelf life issue. Hence, TNB has been using heat shrink technology in totality till now, despite some performance issues.

Heat shrink joint technology

TNB has been using belted PILC cables and screened XLPE cables for the 11kV underground system. Since 1990s, the complete switch to XLPE cables was made whilst limiting the use of PILC cables for predominantly maintenance purpose. The existing heat shrink technology used by TNB is more than 10 years old. Basically, the technology specify the use of heat shrinkable polymeric materials which is imparted by extruding or moulding into the required shape and the crosslinking by either irradiation or chemical means. The components are then warmed and expanded, and allowed to cool in this expanded state. Application of heat will cause them to return to the original shape. The existing joints use by TNB consist of a number of tubes to provide stress control, insulation, screening, and overall protection. The later version of this design has already combined some of these layers such as the insulating and the semi-conducting as a single coextrusion for an easier installation.

TNB is currently used only heat shrink joints for jointing of
the screened XLPE cables. There are two designs used for the joints. The first one is belted design. In this design each core is insulated, but the screening are belted. The insulating tubing is of a high insulation polymeric materials possessing erosion resistance, weather proof, and flame retardant properties. A non-hydroscopic filler is used to prevent movements of the cores. Moisture blocking sealant is used for the water blocking system before applying heat shrinkable protective tubing for the jacketing. This tubing is electrically insulating and UV resistance. The other is screened joint where each core is insulated and the screen carried over with copper braid. The filler, the water blocking system and the jacketing are the same as the previous design.

VLF TESTING OF 11kV CABLES

Very low frequency (VLF) testing of 11kV underground cable was implemented, in the mean time, since December 2000 as part of system-wide effort to gradually “flush out” potential weak point particular joints in the cable system. However, “bad joints” are also replaced by existing heat shrink joint technology in even greater number.

Some of the earlier doubts or concerns related to VLF testing are as follows:-

(i) Duration of test e.g 30 min, 60 min, 0.1Hz or others)
(ii) Effectiveness of testing based on failures on tested cables
(iii) Suitability of VLF testing on PILC cables
(iv) VLF Testing Cycle e.g 3 or 4 year cycle
(v) Testing Waveform (sine wave or square wave)

Based on the experiences and studies done over the implementation period, some of these concerns are already addressed whilst others are still investigated. The optimal testing cycle is still under investigation through close monitoring of sub-system that have completed 100% testing of all cable segments. However, VLF testing has proven to be successful in flushing out a substantial percentage of “bad joints” and thus reducing SAIDI contribution from cable-related faults. To date an estimated 60% of the underground systems are already subjected to VLF testing with the standardized testing procedure of 0.1Hz or 60 minutes.

In the final analysis, as much as VLF testing have contributed to marked reduction in SAIDI contribution from breakdown in operation or service, this is by far a lasting solution as “bad joints” are replaced in duplicates of the same type/made.

PERFORMANCE EVALUATION OF 11kV UNDERGROUND CABLE JOINTS

The next initiative towards seeking a lasting solution to cable joint performance is to conduct a special research project that involves laboratory testing of existing and other joint technologies and types.

The special research project evaluates different types of joints and its design performance. Among the types of joints being evaluated are as follows:

- Heat shrink
- Tape resin
- Premoulded / Slipover
- Cold shrink resin
- Cold shrink hybrid

Sample of each joint technology/type is subjected to the following laboratory tests:

- AC Dry Power Frequency Withstand test
- Partial Discharge test
- Electrical Stress Calculation using computer software
- Heat Cycle In Water test
- Power Cable Water Penetration test
- Mechanical test

Study Methodology

First, all newly installed test samples will be subjected to design confirmation tests, which are based on the IEC Standard 60502-4:

- AC Dry Power Frequency Withstand test
- Partial Discharge test

These tests are done to verify that the designs of joints are within specification.

After that, the test samples will be evaluated based on four parameters, which are:

a) Electrical stress calculation using computer software
   Study on electrical stress on different samples of joint using simulation software such as Finite Element Analysis and Maxwell 2D/3D. In this evaluation, the weakest point in cable joint will be identified. By doing this, the safety factor of each component can be confirmed and improved.

b) Heat Cycle test
   Joint will be placed in a tank and will be immersed in water. The joint will be subjected to thermal cycle test under water for thirty cycles.

c) Water penetration test
   Power cable water penetration test method will be used, this is to observe the ability of the water to penetrate the joint along the cable sheath. This test will be conducted as for the heat cycle test without voltage stress to monitor the water ingress into the joint under maximum operating condition.

d) Mechanical Test.
   Joint will be placed in a tank and will be buried with sand/soil. The joint will be subjected to a mechanical and vibration force to evaluate its mechanical protection design.

Note: After subjecting these sample to (b), (c) and (d) tests, all samples will have to undergo the same electrical tests as stated above (Partial Discharge and AC Withstand). This is to
measure the degradation level that has taken place during the testing.

e) The material tests will be conducted to all test samples to evaluate and compare the microstructure and composition before and after subjected to these tests.

The entire test procedures are to follow the International Electrotechnical Commission (IEC) Standards or equivalent standards. Expert jointers from each manufacturer did the preparations of cable joints. Experts from TNB training department monitored the preparation of the cable joint samples. Specifications and methods of jointing were in accordance with adopted standards by TNB. All tests were performed at High Voltage Laboratory and Advanced Material Laboratories. As for the electrostatic computation, it will be done by the expert from UNITEN (TNB’s own university) suitable Finite Element Analysis software.

Findings

The results and findings for the following tests are as follows:

a) Heat Cycle Test

Partial Discharge test after heat cycle stress showed two lowest rating were assigned cold shrink resin and tape resin joints. These two joints type has exceeded the recommended value of partial discharge in the standard requirement, which is 10 pC. This has indicates that these joints is not suitable to be installed in a heavily loaded circuit with frequent load changes for example in industrial or commercial area. Where as, heat shrink, cold shrink hybrid and pre-moulded joint type has complied and slightly exceeds the standard requirement. This has indicated that these joints are suitable to be installed in the area and in the ranking mentioned above.

b) Water Penetration Test

Partial discharge results after joint samples were subjected to water penetration stress indicate three joint types have shown significant partial discharge value, which are heat shrink, tape resin and cold shrink resin. Tape resin and heat shrink failed the AC withstand test. This clearly indicates that these joints are not suitable to be installed in swampy or high water table area. Where as cold shrink hybrid and pre-moulded joint type complied and slightly exceeds the standard requirement. This indicates that the chances of cold shrink hybrid and premoulded joints surviving in the above mentioned condition is high in comparison to the other types of joint.

c) Dynamic Loading Test

The partial discharge results after the samples were subjected to dynamic mechanical loading stress showed significant increment of partial discharge magnitude in tape resin and cold shrink resin. It could be said that these joints may not perform in the area of heavily traffic loading and frequent vibration condition.

Extended field trial of cold shrink hybrid joint

The so-called extended field trial for cold shrink hybrid is under implementation at selected supply areas in order to further verify and validate its performance in actual operating conditions.
environment. This is necessary before any standardization of the joint technology in TNB distribution system.

UPCOMING INITIATIVES

Apart from the above past and on-going initiatives, the following activities are being planned for implementation.

a. To benchmark practices and conduct more thorough laboratory testing/evaluation methods of joints related to the following issues:
   ○ Water coming through the conductors
   ○ High water table area
   ○ Properties of each material used for the joints

b. Study on performance of mechanical connector in comparison with crimping

c. Study the effectiveness of partial discharge mapping on cables as a possible alternative to VLF Testing.

CONCLUSIONS

TNB is certainly making real progress towards seeking a lasting solution to the MV underground cable joints performance issues. Whilst VLF remains viable in the short to medium-term, a new joint technology with inherent design performance compatible and resilient to the unique physical and operating environment is required.

Apart from putting new joint technologies through its paces in the real operating environment before embarking on full-blown standardization exercise, ther initiatives related to more advanced laboratory testing and special material testing of key components are to follow suit.

REFERENCES: