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Pre Qualification Test on 220 KV Cable System – CPRI Experience

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Abstract

With the development of XLPE cables and associated accessories up to 500 kV voltage level, XLPE Cable Systems are becoming the main back bone of the Power Distribution and Transmission system. The basic requirement of power cable is that it shall withstand the electrical, thermal, mechanical and environmental stresses imposed on it during its expected life of 25 to 35 years. Generally the development of cable for EHV applications is achieved through increased stress design, which demands very stringent quality requirements during production of cables and development of accessories. Since different designs are available for cables and accessories, it is essential to carry out long duration test to establish their compatibility and reliability. IEC 62067 for extra High voltage Cable accessories have incorporated the pre-qualification tests to check the long term reliability of the cable system in service before installation. This paper highlights the details of Pre qualification test on 220 KV Cable system conducted at CPRI for the first time in India.

Keywords: EHV XLPE Cable, Electrical Stresses, Mechanical Stresses, Pre Qualification Test, Thermal Stresses

1. Introduction

The enhancement in usage of XLPE insulation for high voltage and EHV applications has been achieved through the continuous developments in the manufacturing process to reduce the size and number of impurities in the insulation, improving the cleanliness level of material processing, improving the smoothness of semiconducting materials etc. The cable accessories also have undergone various developments in terms of technology, material, and application methodology. With the improvement in quality of cables and accessories, the design stress of cable system is also getting enhanced. Hence Evaluation techniques have become more stringent and both short term and long term tests are conducted in order to ensure the quality of materials used, the manufacturing processes, workmanship and reliability. In order to gain some indications of long term reliability of cable system, CIGRE advised that it is mandatory to carry out long duration accelerated ageing test. This test has been known as, "Prequalification Test". This test needs to be conducted on the complete system comprising the cable, the joints and the terminations in order to demonstrate the performance of the whole system.

2. Pre Qualification Test

This test has to be performed on the complete system which comprises 100 meter length cable, with accessories which are desired to use in service with the cable such as straight through joints, screen separation joints, Gas insulated joints and terminations. IEC – 62067 – 2001 covers PQ test methods and requirements for Power Cables with Extruded Insulation and their accessories for rated voltages above 150kV unto 500kV. Any Global tenders for EHV Cables calls for the satisfactory completion of Pre-Qualification test as per IEC 62067.

"As per the scope of the standard, when the pre-qualification test has been successfully performed on a cable system, it qualifies the manufacturer as a supplier of cable systems with the same or lower voltage rating as long as the calculated electrical stresses at the insulation screen are equal to lower than for the cable system tested".

2.1 Test Procedure

The pre-qualification test shall comprise the electrical tests on the complete cable system with approximately 100 m of full sized cable including at least one of each

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type of accessory. The normal sequence of tests consists of heating cycle voltage test, Lightning impulse voltage test on cable sample followed by examination of the cable system after completion of the tests.

Prior to the electrical pre-qualification test, the insulation thickness shall be measured on a representative piece of the cable to be used for the tests, to check that the thickness with respect to the declared nominal value. If the average thickness of the insulation does not exceed the nominal value by more than 5%, the test voltages shall be the values specified for the rated voltage of the cable. If the average thickness of the insulation exceeds the nominal value by more than 5% but by no more than 15%, the test voltage shall be adjusted to give an electrical stress at the conductor screen equal to that applying when the average thickness of the insulation is equal to the nominal value. The cable length used for the electrical type test shall not have an average thickness exceeding the nominal value by more than 15%.

2.2 Test Arrangement

As per the relevant standard, the cables and accessories are arranged to reflect the actual service conditions of installation and design, such as direct burial under soil, through HDPE pipe, through tunnels and laying in air with and without rigid fixation, etc. After the arrangements are done, the following tests are to be conducted sequentially to check the reliability of complete system in long run.

2.3 Heating Cycle Voltage Test

The Cable system incorporating all accessories and installation conditions has to undergo heating cycle voltage tests. The complete assembly shall be heated by conductor current until the cable conductor reaches a temperature 0^0C to 5^0C above the specified maximum working temperature of conductor during normal operation. In case of XLPE insulated cables, the working temperature is 95^0C. The heating arrangements shall be selected so that the cable conductor attains the temperature specified above, remote from the accessories. The duration of heating period has to be minimum of eight hours. The conductor temperature shall be maintained within the stated temperature limits for at least 2 hours of each heating period followed by a cooling period of 16 hours. A voltage of 1.7 U_0 shall be applied to the assembly during the whole test period of 8760 hours. The cable assembly has to undergo minimum 180 number of such heating and cooling cycles. During this time, no breakdown shall occur.

2.4 Lightning Impulse Voltage Test

The test assembly which has passed the heating cycle voltage test shall be subjected to Impulse voltage Withstand test. The test shall be performed on one or more cable samples, with a minimum total active length of 30m, cut from the assembly with the cable conductor temperature 0°C to 5°C above the maximum conductor temperature in normal operation. The conductor temperature shall be maintained within the stated temperature limits for at least 2 hours. The cable samples shall withstand without failure 10 positive and 10 negative voltage impulses of the appropriate values.

2.5 Examination

After the Heating Cycle Voltage Test and Impulse withstand test, examination of the cable system with unaided vision shall revel no signs of deterioration (e.g., electrical deterioration, moisture ingress, leakage, corrosion or harmful shrinkage), which could affect the system in service operation.

3. Prequalification Test at CPRI

The Cables laboratory at CPRI, Bangalore has full-fledged facilities in the areas of Testing and Evaluation of Power Cables up to 400 kV covering different type of cable insulation. Presently, CPRI is the only laboratory in India where test facility exists for type tests and prequalification tests on EHV Power Cables as per the relevant international standards. The various test facilities at CPRI associated with Pre qualification test on EHV cable system are shown in Figures 1 to 3 below.

Figure 1. 600 kV, 4200 KVA transformer.

Figure 2. 4000 Amps Heating System.

Figure 3. 2400 kV, 240 kJ impulse generator.

3.1 PQ Test Set Up and Arrangement

As prequalification test is introduced to validate the long term performance (assuming about 40-year design life) of the complete cable system under simulated field conditions with special focus on the cable and accessory insulation characteristics, the cable core/accessory interfaces and the thermo-mechanical behavior over time, all the service conditions needs to be reflected in laying and installation of cables and accessories. The cable was laid partly in air and partly underground. The accessories employed are oil filled terminations at both ends, insulated cross bonding joints, straight through joint and SF6 back-to-back joint. As the result of the test dependent upon the actual laying conditions, part of cable was laid through duct, partly through HDPE pipe under soil, partly directly under soil, and partly through air. The temperature of the cable loop was recorded at different positions along the cable route to ascertain the highest temperature which was taken as reference temperature. The similar highest temperature condition was simulated with the dummy cable for taking as referee throughout the test duration of one year. The cable under soil was laid at a depth of 1.2 metres and was made to take a u bend maintaining the minimum bending diameter.

The cable in underground was laid on sand bed of 200 mm (approx.) thick and back filled with sand for 200mm (approx.). The underground trench was filled with mother earth.

For conductor temperature measurement, dummy Cable of length 20 meters was laid underground, parallel to the main test loop, with 4 metres through HDPE conduit pipe of 1 feet diameter. Thermocouples were fixed on conductor and outer sheath of dummy cable at the cable-laid undergrounds, inside the HDPE pipe. The temperatures of the test sample at different positions of sample were monitored. The observed highest temperature inside the HDPE pipe underground is monitored continuously during the Heating cycle voltage test.

The cable end terminations mounted on stands were shorted as shown in Figure 4, for carrying out the test. Figure 5 shows the SF6 back to back terminations connected with the system for testing.

The test loop diagram connected for testing is highlighted in Figure 6.

Figure 4. 220 kV test terminations.

Figure 5. SF6 back to back joint.

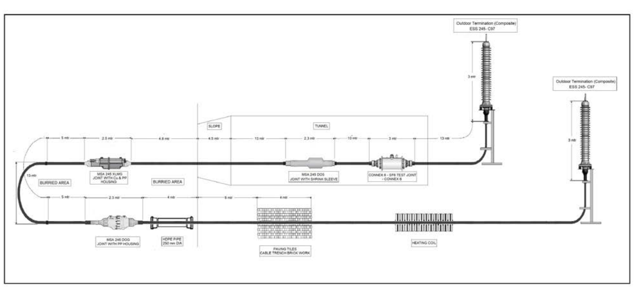

Figure 6. Test loop diagram.

The cable was laid partly through open tunnel, partly through closed tunnel, partly through HDPE pipe under soil, as shown in Figures 7, 8 and 9.

Figure 7. Cable laid in air through closed tunnel.

Figures 8 and 9. Cable laid through HDPE pipe under soil and cable laid in open tunnel with fixed conditions.

3.2 Challenges and Lessons Learnt

One major challenge for carrying out this long duration test is setting the current for the conductor temperature of 90 to 95^0 C throughout the duration of one year. The temperature of conductor is ascertained by checking the outer sheath temperature of test sample with the dummy cable sheath temperature and the conductor temperature through which the same current is passed. As the temperature of outer sheath will be different at different locations, it is mandatory to keep both the temperature monitoring points at dummy cable and test sample at similar location, where the outer sheath temperature remains same throughout one year, irrespective of varying atmosphere temperature and other seasonal conditions. Hence, in this case, both the test sample and dummy cable was laid underground through HDPE pipe. The temperature of outer sheath inside the HDPE Conduit for the test sample and dummy were found to be same throughout the 180 cycles.

4. Conclusion

The test procedure, sequence, test set up and challenges to conduct the pre qualification test on EHV cable system to ascertain the long term reliability in service is listed out in this paper. With the development of high stress cable with highly sophisticated manufacturing process and good quality of raw materials, the need for carrying out prequalification test is highly mandatory for EHV cables to ascertain its integrity and reliability.

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6. References

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