The Impact of Standardized Cable System Design on Transmission System Reliability

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Abstract: ***Dubai Electricity and Water Authority (DEWA) has for many years sustained its position being one of the best power utility companies around the world. Sustaining such a position was associated with a journey accompanied by several challenges which in turn required various structural enhancements to ensure design, installation, testing & commissioning, operation and maintaining its network reliability at the highest standards possible. In the area of Transmission Cables specifically, DEWA has formulated its own specification to standardize the cable and cable accessories design suitable to its network. This specification was developed by combining historical data, site experience, and relevant international standard such as IEC, IEEE, CIGRE, AEIC, BS standard etc. In addition, periodic revision of specification is ensured as a part of continuous improvement, that is to sustain a high standard of best practices, and become a target entity for benchmarking.***

Keywords: Transmission, Cables, Cable System, XLPE, Accessories, Joints, Terminations, Design, Installation, Testing, Commissioning, Standardization

1. Introduction

In this paper, we shall go through the timeline from the period prior to design standardization and the drawbacks accompanied by the non - standardized designs, followed by the journey of developing a standard design and finally the enhancements sensed through standardization of both cable and cable accessories designs. The paper will highlight the impact of gradually moving from non - standardized design of cable and accessories towards standardizing the design of the components and how the benefits were sensed throughout the past few years. The primary focus will be on the design of 132 kV cables followed by the design of 132 kV accessories. Considering the continuous and rapid network expansion in Dubai (with around 56.87% network expansion in term of 132KV cable length during the last 10 years), Having standardized cable and accessories design impacts project schedule positively as minimal time frame is required in the Design & Engineering phase. In addition, uniformity of cable and accessories design enhances interchangeability and optimizes spare requirements.

This paper also deals with interchangeability of cable accessories (GIS end termination, Transformer end termination) involving different cable sizes and interfacing of cable termination with GIS cable head and transformer cable head with reference to standards IEC 60859, IEC62271 - 209 & BS EN 50299.

1) 132 kV Cable Design

XLPE cables are globally used in Transmission networks all around the world as the latest type of cable for such usage, replacing the conventional oil insulated cables used earlier. DEWA adopted the usage of XLPE cables as an alternative to the previously used oil filled type cables which were prone to leakage of oil and difficult to maintain oil pressure resulting in cable failures. Oil leakage contaminates the soil and negatively impacts both the environment and cost, having more restoration time.

Compliance with international standards was essential to be ensured and confirmed during the transition process. Nevertheless, DEWA took a step further building its own specification in terms of design and size of 132 kV cables in its network as a move to control its system and to provide flexibility when it comes to modification and maintenance requirements. Having a standard size and design plays a key role in ease of handling and rectification/modification to the system as and when required, as finding a match in terms of cable/accessory would be challenging in case of major design/size variation.

In DEWA 132kV XLPE design, the conductor material, cross section and the main insulation nominal thickness are specified. According to IEC 60840, the dielectric electrical stress at nominal voltage at the conductor screen (E_i) and at the core/insulation screen (E_o) can be calculated as below:

$$E_i = \frac{2U_0}{d_{ii} \times \ln(D_{io} / d_{ii})}$$

$$E_o = \frac{2U_0}{D_{io} \times \ln(D_{io} / d_{ii})}$$

where:
$D_{io} = d_{ii} + 2t_n$
D_{io} is the calculated nominal outer diameter of the insulation, in mm
d_{ii} is the declared nominal inner diameter of the insulation, in mm
t_n is the declared nominal insulation thickness, in mm
U_0 is the rated r. m. s. power - frequency voltage between each conductor and screen or sheath for which cables and accessories are designed

Therefore, ensuring that the conductor cross - section and insulation thickness are fixed, this will satisfy the type test range of approval requirements as per the IEC 60840

a) The calculated nominal electrical stress and the impulse voltage stress at the cable conductor screen calculated using nominal dimensions do not exceed the respective calculated stresses of the tested cable system (s) by more than 10 %.

b) The calculated nominal electrical stress and the impulse voltage stress at the cable insulation screen calculated using nominal dimensions do not exceed the respective calculated stresses of the tested cable system (s).

c) The calculated nominal electrical stresses and the impulse voltage stresses calculated using nominal dimensions within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed the respective calculated stresses of the tested cable system (s).

When type tests have been successfully conducted on one or more cable systems with specific cross - sections, as well as the same rated voltage and construction, their type test approval shall be deemed valid for cable systems, even if they have different cross - sections.

As a result of the standard design of cable system that DEWA adopted, all type tested cables of a voltage group does not exceed that of the tested cable system in the network, and belonging to the same voltage group share rated voltages with a common Um value (the maximum value of the "highest system voltage" for which the equipment may be used), which is the highest voltage for equipment, along with identical test voltage levels are compatible with each other.

2) 132 kV Cable Accessories Design

The accessories in a cable system are considered the weakest points of the system, making them critical to standardize and guarantee their safety during service. As is the case for the cable, accessories also have a unique slot in terms of standards in DEWA. Complying with international standards, DEWA has also developed its own standard for cable system accessories (including joints and terminations), based on historical data and lessons learnt from experience.

Utilizing a uniform design for cable accessories provides many benefits for procurement, storage, and maintenance tasks. To begin with, standardization makes the procurement process more efficient by making it easier to choose materials and components, thus decreasing the requirement for in - depth research and evaluation. This saves time and guarantees consistency and compatibility in different projects or systems. Furthermore, standardized designs make it easier to store items efficiently by using consistent components and specifications, which leads to better inventory management and decreased storage space needs. Additionally, standardized designs simplify maintenance tasks and reduce costs. By having standardized components and procedures, maintenance workers can easily replace parts, leading to decreased downtime and less reliance on specialized training or expertise. In general, adopting standardization improves efficiency, dependability, and cost efficiency across the entire lifespan of a cable system.

2. Pros of Standardization

There are several advantages of standardizing both cable and accessory designs. Those advantages include and are not limited to:

- Enhances project life cycle.
- Engineering phase can be accomplished in a minimal time - frame.
- Spare requirements are met easily with minimum stock of spare.

3. Previously Encountered Issues and the Impact of Non - Standardized Designs

Prior to developing a standardized design for cables and accessories, several cable manufacturers were having different nominal insulation thickness in their cables, creating a challenge to find suitable accessories (specifically joints) whenever replacement was required due to faults or network modification. This created a limitation of selection given that not all joint manufacturers had suitable accessories for cables with different insulation thickness.

4. Conclusion

In conclusion, after several years of experiencing design standardization and enhancing the standards based on stakeholders' feedbacks in parallel with Dubai's rapid growth requirement, it has been proven that having a standard design for Transmission cables and their accessories positively impacted the project delivery time to cope with the rapid network expansion, minimizing the cost of contingency spares and sustaining the reliability of the network through quick restoration of failed cables/accessories.

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