DESIGN AND QUALIFICATION OF 500 KV DRY TERMINATIONS AND JOINTS FOR EXTRUDED CABLES

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ABSTRACT

Electrical stresses in cable terminations and joints at 500 kV voltage level are increasingly high and design margins are lower than ever before. Designers are selecting materials that can perform better in the field and in the same time be efficient in the manufacturing process. This paper presents one design approach that creates dry environment for elastomeric stress control elements in cable accessories and prevents change of physical properties due to swelling in insulating compounds.

KEYWORDS

Cable Terminations, Joints, molded rubber, XLPE cable, dry design, type tests, prequalification tests

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INTRODUCTION

Number of global drivers are shaping the configurations of modern T&D networks and are creating a need for underground power delivery at HV and EHV voltage levels. Integration of renewable energy sources (RES), increasingly severe weather patterns that result in frequent power outages in OH grid, and growth of densely populated urban centers and their respective loads are the main factors that are driving undergrounding at extra high voltages.

Current maximum commercially available AC system voltage level for underground power cables and their accessories – terminations and joints – is at 500 kV. Technology of choice for cables at these voltages is set to XLPE (cross linked polyethylene) while terminations and joints are more diverse regarding materials and designs that are deployed.

This paper explores one design approach for 500 kV rated terminations and joints, provides underlying reasoning and describes steps undertaken in qualification and testing of these accessories.

TECHNICAL CONSIDERATIONS AND DESIGN PHILOSOPHY

At 500 kV system voltage nominal operating line to ground voltage that equipment is continuously subjected to is 289 kV AC, and nominal electrical stress at cable insulation screen that joints and terminations need to withstand and effectively distribute is in the range of 7 kV/mm or more.

During the qualification process, relevant industry standards require accessories to be tested at multiple times higher AC voltages and stresses while subjected to elevated temperatures and accelerated ageing. IEC for example requires AC withstand tests up to 100% higher than nominal, while IEEE 48 standard for cable terminations requires three times higher AC test (870 kV for 15 minutes).

It is easy to imagine that these electrical, mechanical and thermal stresses must be taken into consideration early in the design process, when selecting dielectric material for factory molded (pre-molded) stress cones and joints.

To become more efficient both in the factory and in the field, designers and engineers are facing a mounting pressure to shrinking nominal design margins. This in return requires careful consideration of ageing mechanism of dielectric material used for stress cones and joints, and often leads to necessity to tighten the control over rate of change in physical properties of the material.

The design and qualification approach that was used by G&W Electric Company for line of 500 kV cable accessories was to remove factors that will have a long-term effect on dielectric material for pre-molded accessories.

This paper will discuss how this design philosophy translated in selection of the materials, product design, manufacturing and field challenges and development and implementation of testing programs and their results.

DRY DESIGN OF THE ACCESSORIES

Stress control parts are typically exposed to insulating fluid that is often used in EHV outdoor cable terminations. These parts swell over time and change their basic electrical and mechanical properties to some degree.

The examples of swelling characteristics of two different grades of silicone rubber (R1 and R2) in different insulation compounds are shown in the table below.

	Fluid A		Fluid B		Fluid C		Fluid D	
	R1	R2	R1	R2	R1	R2	R1	R2
Days to saturation	93	85	70	70	64	30	65	50
Weight gain	14.0 %	13.0 %	2.4 %	2.3 %	1.1 %	0.3 %	1.5 %	0.7 %
Tension set	11.9 %	11.5 %	9.3 %	11.5 %	6.3 %	5.6 %	6.8 %	7.3 %
Shore A drop	15%	10%	3%	0%	0%	4%	0%	2%

Table 1: Swelling characteristics of two different grades of silicone rubber and change of mechanical properties

The decision was made to isolate elastomeric pre-molded stress control parts from insulating fluid, effectively forming