ON THE RAISING APPLICATION OF POLYMERIC POST INSULATORS

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1 Abstract

The paper deals with the application of polymeric post insulators for different purposes. Their specific advantages are discussed. In a second part, the failure mode behaviour is shown and correlated with the recommendations of IEC Draft 61952. The terms "Maximum Design Cantilever Load (MDCL)" and "Specified Cantilever Load (SCL)" are explained by practical examples.

2 Introduction

Polymeric post insulators, in this paper a used term for insulators with a glass-fibre reinforced resin core with polymeric housing, incorporate the known advantages of polymeric insulators such as high ratio between mechanical strength and weight, pollution performance (especially for Silicone Rubber (SR)-housing) and brittle unsensitiveness. In comparison to porcelain posts, the deflexion due to the lower Young`s-Modulus has to be considered in the design stage. Another interesting issue is the application of post insulators for "public pleasing" compact line designs - cases in which Right of Ways (ROW) can be of essential interest. This can be illustrated by figure 1 (/1/) as an example from the United States (230 kV). The ROW are almost identical for both designs, but include four systems in 1b. Further the span length is longer for the polymeric post, which reduces the number of poles required.

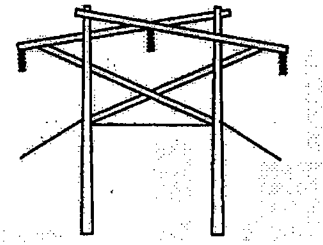

Figure 1a: Wood H-Frame Single Circuit, 170 m typical span, ROW 34 m

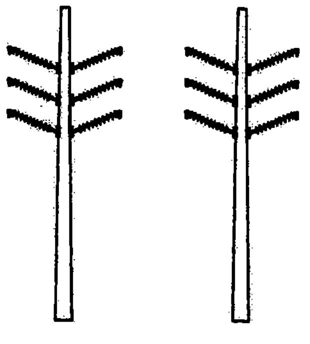

Figure 1b: Single Pole Two Double Circuits, 230 m typical span, ROW 35 m

3 Application

3. 1 Railway Catenary Support Insulators

In the years from 1979 to 1992, the Swiss railway company BLS expanded their 240 km track system to be a double track /2/. Approximately 40 km of the track length are within a tunnel. The single phase to ground voltage is 15 kV at the railway-typical frequency of $16^{2}/_{3}$ Hz. The specific requirements for this application have been:

- reduced weight for increased train speed
- high failing load
- maintenance-free insulator

The weight has been reduced by more than factor 2 and the mechanical strength (Maximum Design Cantilever Load) was specified to be 2.5 kN corresponding to the porcelain posts, which have been used since 1913. The SCL of the polymeric post is 25 kN, which provides a high safety margin, while the diameter of the load-bearing rod had to be selected for a limited deflexion. The request for maintenance-free insulation was a sophisticated challenge at this time – the hydrophobic behaviour of polymeric housing materials was initially known, but the lifetime of this property as well as appropriate artificial tests to deduce service performance were not available. So the use of Silicone

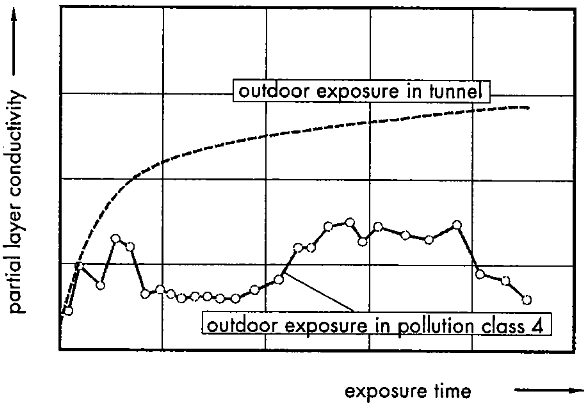

Figure 2: Principal pollution accumulation for exposure without self-cleaning

Rubber housing (RTV-grade) made by low-pressure injection moulding was a visionary decision. Due to the uncertainty about lifetime, the creepage length has been increased in comparison to the porcelain design (1115 mm instead of 700 mm). Using the terminology of IEC 60815, a specific creepage length of 43 mm/kV was designed, because the 27 mm/kV of the porcelain post has not been sufficient and required cleaning at least twice a year. The principal pollution stress in comparison to outdoor application with intermediate cleaning periods due to rain is shown in figure 2.

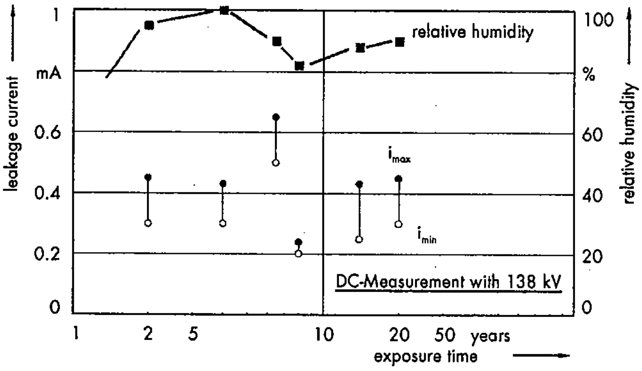

Figure 3: Evaluation of hydrophobicity

Presently a scientific test programme is ongoing to investigate the electrical and mechanical performance of the insulators after up to 20 years of service under these conditions. Initial measurements of the pollution layer provided ESDD-values up to 0.6 mg/cm^2 and NSDD-values up to 17 mg/cm^2, which gives an indication about the specific pollution containing dirt, brake dust and abraded particles from the catenary commutator. In-service measurements of hydrophobicity have been carried out by using a cable loop with SR-terminations placed as reference source in the tunnel (figure 3). It shows that the hydrophobicity is measurable after 20 years, despite the visual appearance that the surface is fully covered by a pollution layer. Today there are more than 4000 post insulators installed in this tunnel (figure 4), they have never been cleaned and have shown neither a mechanical nor electrical failure.

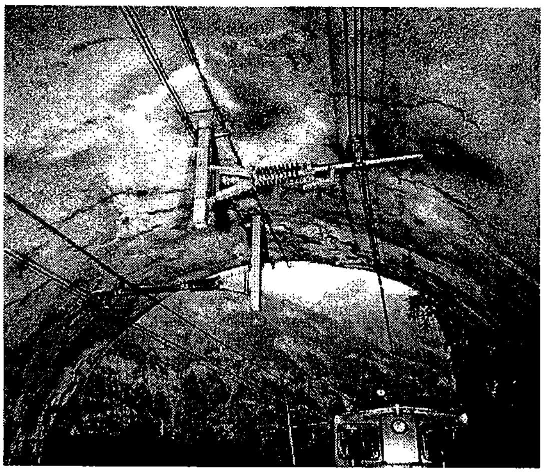

Figure 4: Catenary structure in the BLS-tunnel

3.2 Posts for Shielded Wire Scheme (SWS)

For the rural electrification of developing countries some ideas have been realized to use existing HV-transmission lines by introducing a Shield-Wire-Scheme /3/. A typical schematic is shown in figure 5: The earth wire is energized at 20...34.5 kV and fed from one end of the line. By using distribution transformers, electrical power can be supplied to villages in the vicinity of the transmission line. As a cost-effective solution, the soil is used as ground return. For such a project (132kV line in Ethiopia – Ghedo-Nekemt-Ghimbi), the application of polymeric insulators has been investigated to fit into the tower design (principle in figure 6). There have been two alternatives for the SWS-installation:

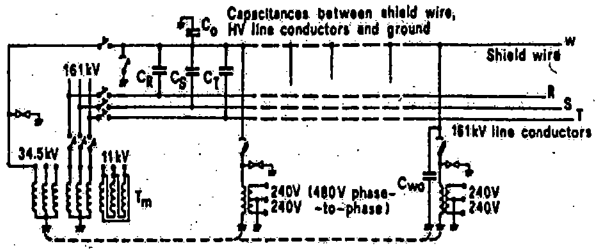

Figure 5: Principle of Shield Wire Scheme

- rigid strings made of glass cap and pin
- polymeric post insulators

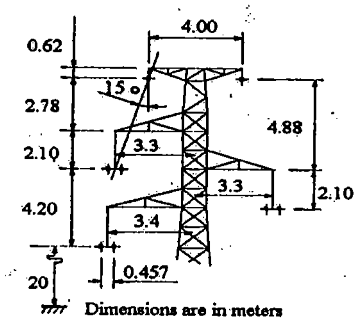

Figure 6: Tower configuration for SWS

The requirements for the post insulator has been determined by the conductor (ACSR 76.9 mm^2) and the span length for this transmission lines to be in-between 140...700 meters. The load calculation required the following mechanical values:

- ultimate cantilever strength (SCL): 22 kN
- broken wire withstand load: 18 kN
- type test load (equivalent to MDCL): 18 kN

Corresponding to the specification, a post type insulator has been designed by using the modular principle of housing manufacturing (figure 7). The insulator is length-wise an approximate 69kV-unit to handle the clearance due to different span length. The insulation co-ordination is adjusted by the horns. The simulation

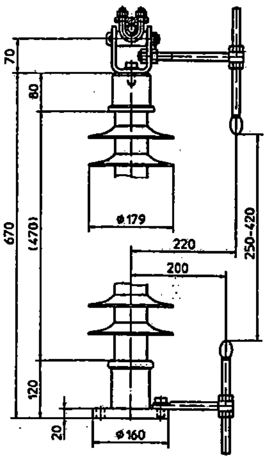

Figure 7: Polymeric post insulator design

of broken wired was passed without particularities (figure 8). The simulated failure event took place at 125 seconds followed by the application of a continuous load. The verification of the SCL provided values more than 31 kN, which includes a safety margin of approximately 40% in comparison to the specified value. The 96hour-test for determination of MDCL was passed with 18kN (visual analysis), which corresponds to the 58%-value of SCL. Typical requirements of technical specifications are MDCL/SCL ≤ 40%!

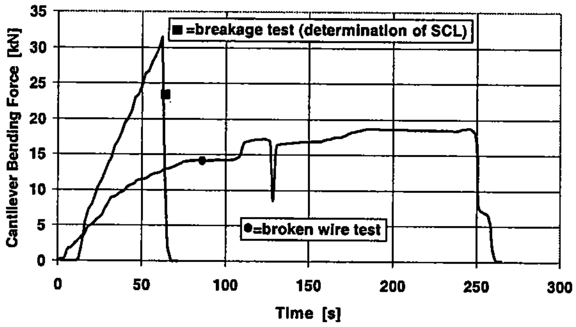

Figure 8: Mechanical testing of the SWS-post insulator

3. 3 Braced Line Post Application for 420 kV

Due to increased energy demand, the voltage up-grade of existing transmission line has become a popular way for utilities to react on the situation. The increase of voltage is related to increased Right of Way (ROW), which causes in densely populated areas problems. As reported in /4/,a new 420kV-line in Switzerland operated by EOS nearby Lausanne had to be erected. The solution consisted in the introduction of a compact line design for 3 towers employing horizontal vee insulating crossarms (figure 9). Extensively mechanical tests have been performed to investigate the static and dynamic behaviour of the arrangement. As basis and reference, the static values have been determined to simulate the material limits of the individual components. Afterwards the complete crossarm was tested with simultaneous recording of specific stresses. All the time, the stresses have been in the elastic phase. Considering this result and the safety factor of at least 3.1, the utility became confident into the solution to use polymeric insulators. The post type insulator is made of a hollow core to provide sufficient mechanical resistance against buckling for the compression forces in axial post direction. The internal space of the hollow core has been filed with a permanent-elastic material to prevent condensation and internal partial discharges. The line (figure 10) is energized for approximately 2 years and withstood the heavy storm in December 1999 without any problems.

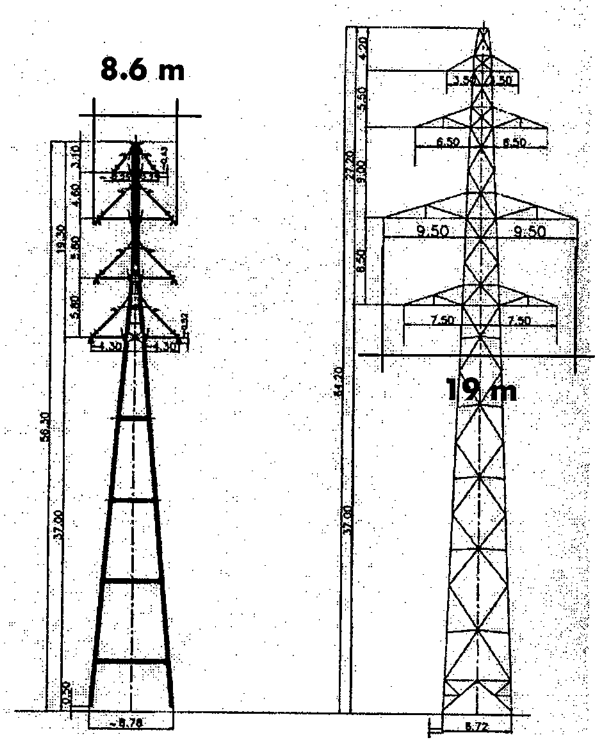

Figure 9: Comparison between compact and conventional lattice tower

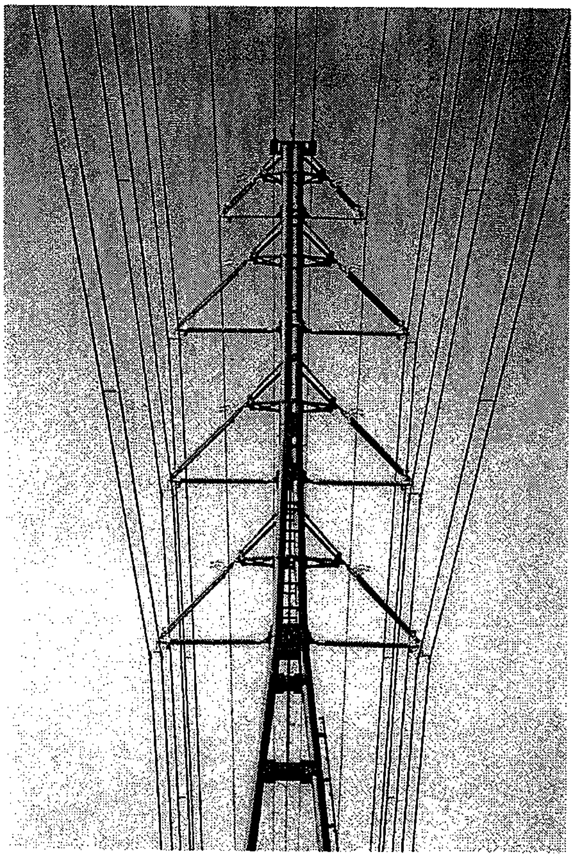

Figure 10: Real life appearance of the compact tower