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ADITYA BIRLA GRASIM

Study Committee B2

Over Head Lines PS1

10445_2022

Selection of Porcelain Cap and Pin Insulator Components for Transmission Lines in High Altitude and Exposure to Ice and Snow

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Motivation

- Over head transmission lines built at a high altitude will exert influence on performance of insulators due to changes in air pressure, temperature and humidity. Insulators will be subjected to ice accumulation for an extended period (nearly six months) each year due to freezing rain or drizzle, in-cloud icing, icing fog, wet snow, or frost.
- In recent years, several incidents related to the flashover of iced insulators have been reported worldwide due to excessive ice accumulation and dynamic loads caused by wind, in the presence of ice and snow on insulators. Therefore, it is imperative to know the effects of these atmospheric conditions on the specific components of insulators, otherwise it may result in premature aging, reduction of operation performance or even failure.
- International guidelines are not available for selecting individual components of insulators with respect to ice and snow.
- This paper describes the important characteristics that need to be considered for selecting various components of insulator for applications in high altitude.

Method/Approach

- The adverse ambient temperature ranges of +35 °C to -45 °C in high altitude region will result in deterioration of properties of various components of insulators such as porcelain body, metal components, and cement in long run.
- To mitigate the above suitable modifications needs to be considered.
- Artificial Pollution test to be conducted to validate the performance of insulators.

Objects of investigation

- Selecting suitable insulator type
- Selecting suitable microstructural phase content for porcelain body
- Suitable modifications in metal components
- Enhancing mechanical property of cement considering the exposure of insulators to ice and snow
- Optimization of profile parameters of insulator’s external design

Experimental setup & test results

- Microstructural phase analysis porcelain body
  - Amorphous (Glass Phase) : 56 %
  - Mullite (Crystalline) : 12 %
  - Corundum (Crystalline) : 23 %
  - Quartz (Crystalline) : 09 %
- Mechanical properties metal grades

Property	Grade 450/10	Grade 400/18
Tensile Strength (N/mm²)	Min. 450	Min. 400
0.2% Proof Strength (MPa)	Min. 310	Min. 250
Elongation (%)	10	18
Min. Temperature to maintain +20 °C tensile elongation (°C)	-25	-75

- Pollution Performance of design optimized (Form Factor 1.56, Creepage Factor 3.35, String Factor 0.84) insulators withstood Salinity of 160 kg/m³ compared to 80 kg/m³ of normal insulators.

Discussion

- Use of high crystalline content (44%) high alumina body will improve thermal shock resistance.
- There is 10% decrease in tensile strength of 400/18 grade at 20 °C. But, ductility is stable up to -75 °C. This is very critical to withstand loads caused by snow combined with wind.
- Cement developed using special additives helped to gain high-early-strength, reduce shrinkage and expansion during curing.
- Design optimized insulators showed 100% increase in performance level. This is because of the improved geometrical parameters.

Conclusion

- Porcelain cap and pin insulators supplied for 220/66kV transmission system built at a height of 3,000-4,000 meters above sea level were performing satisfactorily for the past 3 years. The salient aspects of selection of materials & components of porcelain insulators are:
- High alumina porcelain body with 44% crystalline content to be used.
- The metal components having higher elongation shall be used to mitigate adverse effects of loss of ductility.
- Cement having high-early-strength gain properties to be used to mitigate the accumulative effect of successive freeze-thaw cycles that causes cracking.
- Optimization of profile parameters helped to achieve 100% increase in pollution performance.

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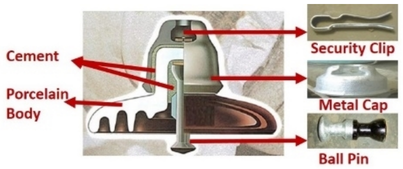
Insulator Type

- Components of Porcelain Cap & Pin Insulator



- Porcelain as an insulating material has more than one century of proven service history in terms of electrical, mechanical, thermal and environmental stress withstanding capability.
- The chemical stability of porcelain offers environmental and ageing resistance, thus making it suitable for long term use.
- At high altitude, the main negative effect is accumulated ice or snow on insulators resulting in excessive mechanical loading, transmission lines and substations hardware that can either lead to impeding proper operation of apparatus or, in extreme cases, to major collapsing of the lines with dramatic consequences.
- The fully vitrified porcelain insulator, due to firing at temperature above 1250 °C, imply satisfactory mechanical performance under these conditions.

Porcelain Body

- High Alumina body was used considering the adverse ambient temperature range of +35 °C to -45 °C in the region, which may affect the thermal shock resistance of porcelain body in long run.
- In silicate based porcelains, presence of undissolved quartz lead to initiation of non-coherent interface in structure, micro crack formation and decrease of mechanical properties.
- The above is avoided in insulators manufactured using High Alumina Body.
- The thermal shock resistance could be improved by reducing the amorphous content and increasing the crystalline content in the microstructure of fired porcelain body.
- High Alumina Body used for manufacturing these insulators contains 44% crystalline content (Mullite, Corundum and Quartz). Moreover, the decrease of glass phase (amorphous) in High Alumina Body lead to increase in electrical strength in these materials. and thus, they offer dual advantages of ensuring increased mechanical and electrical performances when subjected to freezing conditions.

Metal Components

- The CIGRE Work Group B2-03 report revealed that 55% of mechanical failures were due to hardware breakage.
- Most of the hardware failure were caused by no-fatigue. Hence, the primary adverse effects that low temperatures cause are loss of ductility, increasing brittleness, and making the metals to be more sensitive to impacts.
- To increase the ductility (elongation) and impact toughness of metal parts, metal caps were manufactured with Grade 400/18 of IS:1865 grade
- The security clips were manufactured with Phosphor Bronze (Gade 1 of IS:7814), having mechanical strength along with desirable ductility, instead of generally used austenitic stainless steel (AISI-304).

Cement for Assembling Metal Parts

- The porcelain insulator includes ceramic body, iron, and cement, which are three different components, with a bitumen coating and grog band between them.
- The cement part acts as a bridge connecting all the above constituents of the porcelain insulator.
- The mechanical property of cement is very important, especially when the insulators are exposed to ice and snow.
- Generally, Ordinary Portland Cement (OPC) grade 53S is used for cap-and-pin insulators manufacturing. But, for this application a special grade cement was developed using special additives.
- The special additives helped the cement to gain high-early-strength, reduce shrinkage and expansion during curing.
- The severe exposure condition of insulators was considered as exposure to cycles of freezing and thawing. The accumulative effect of successive freeze-thaw cycles and disruption of concrete can eventually cause cracking.
- Hence, the autoclave expansion of cement was controlled to minimum level and the mechanical strength of the cement was increased to withstand pressure developed due to expansion of water when it freezes.
- Thus, the accumulative effect of successive freeze-thaw cycles that causes cracking are avoided in service conditions at high altitude.

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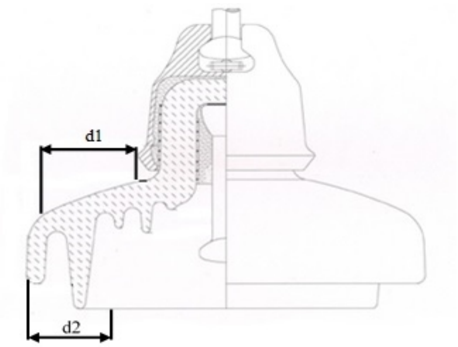
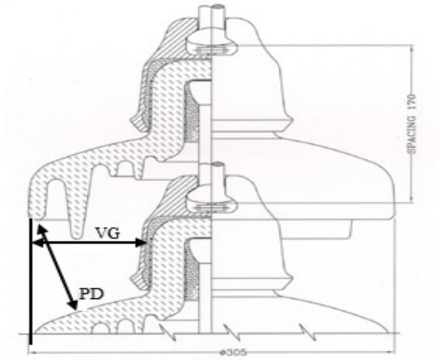
Modification in Design

- Improvement in profile of porcelain insulators were carried out by optimization of important design parameters
- The existing design has been modified by considering various aspects such as Form Factor (FF), Creepage Factor (CF) and String Factor (SF) to develop the new design. This is to get better pollution performance of these insulators.
- The optimization of FF has been done on full creepage distance (CD), which is divided in to Short Creepage Distance (SCD) with 15 or 20 mm each and the FF calculation has been done using the following equation.
- $\text{Form Factor} = \dfrac{\text{Short Creepage Distance (SCD)}}{\text{Diameter of each SCD X } \pi}$
- To derive the CF, the linear portion of porcelain shed length has taken as d1 and from rib side, where the go-No go gauge is touching has taken as d2. The details are given in the following figure. The formula used for calculating is: CF = = CD / (d1+d2)

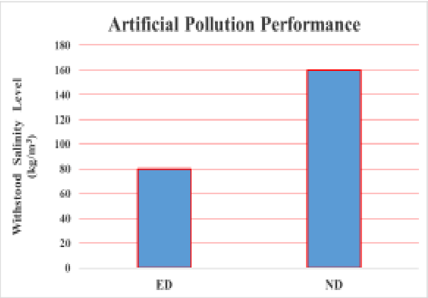


- Figure showing details of Creepage Factor of Porcelain Insulator
- The SF is determined using the vertical gap (VG) between outer shed and head of two consecutive disc insulators, in a string as detailed in the following figure. The perpendicular distance (PD) between previous outer shed and next disc outer surface. The SF has been calculated using the formula:-
- SF = VG / PD



- Figure showing Details for String Factor Determination

Pollution Performance of Design optimized insulators



- Figure showing effect of design optimization in pollution test
- The pollution performance test was carried out artificially, as per IEC 60507, on these insulators showed remarkable improvement.
- The improvement in pollution performance of new design (ND) samples over existing design (ED) is evident from the above Figure.
- The design optimization helped to achieve 100% increase in performance level.
- This is because of the improved geometrical parameters i.e. FF, CF and SF.