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The Effectiveness of Mitigation Scheme on Electric Field Intensity (Stress Control) for Overhead Line Glass Insulator

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PRESENTATION OUTLINE

- Introduction
- Characteristics of The Mitigation Scheme
- Modelling Technique of Overhead Line Glass Insulator
- Effect of Pollution and Grading Scheme on Overhead Line Glass Insulator
- Conclusion

INTRODUCTION on Overhead Line Insulator

3 Category of Overhead Line Insulators

- Suspension insulator
- Pin insulator
- Strain insulator

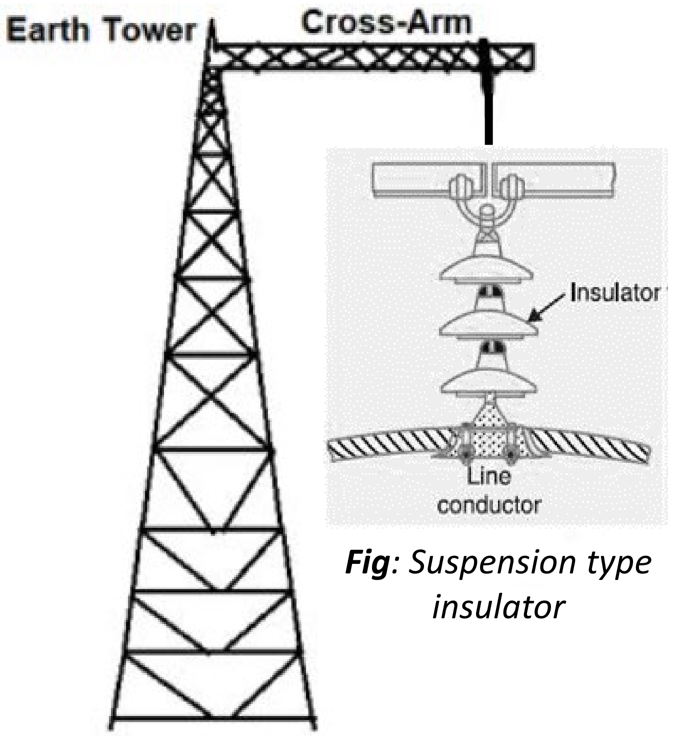


***Fig**: Suspension type insulator*

Insulator materials

- Porcelain
- Glass
- Epoxy resin
- Polymer composite

Share a common issue with the contamination affecting the dielectric performance of the insulators.

Therefore, electric field enhancement techniques (stress control) is required. The mitigation schemes include:

- Field grading material (FGM)
- Micro-varistor zinc oxide (ZnO)
- Grading ring
- Corona ring

CHARACTERISTIC of The Mitigation Schemes

Field Grading Material (FGM)	Zinc Oxide (ZnO) Micro-Varistor	Grading ring	Corona ring
• Two (2) types of FGM are listed as resistive and capacitive grading material (based on their nature displacement of the insulation material). • Superior on controlling the electrical stress. • Application of FGM: high voltage motors and cable terminations.	• ZnO is an inorganic compound and insoluble in water. • Wide-gap semiconductor with good transparency, high electron mobility. • The non-linear V-I characteristic and ability to absorb energy were the key factors to its superior electrical performance.	• It works by redistribute the electrical stress that eventually will divert the corona discharge elsewhere on the insulator profile. • The design process of the grading rings needs to be done delicately to prevent the corona discharge to occur.	• A metal ring that fitted at both ends; the HV conductor and the earth terminal, since the high electric field was spotted at those area. • Helps to reduce disturbances on telecommunication signals and to reduce hissing noise.

MODELLING TECHNIQUE of Overhead Line Glass Insulator

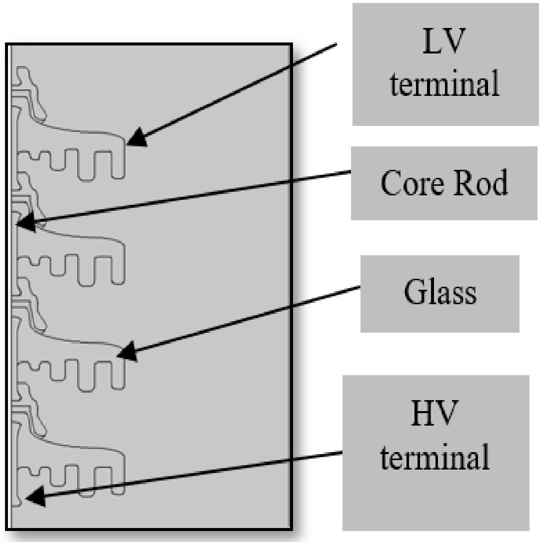
Table 1: *Component description for glass insulator*

Component description	Length (cm)
Height	44
Disc radius	12
Creepage length	190

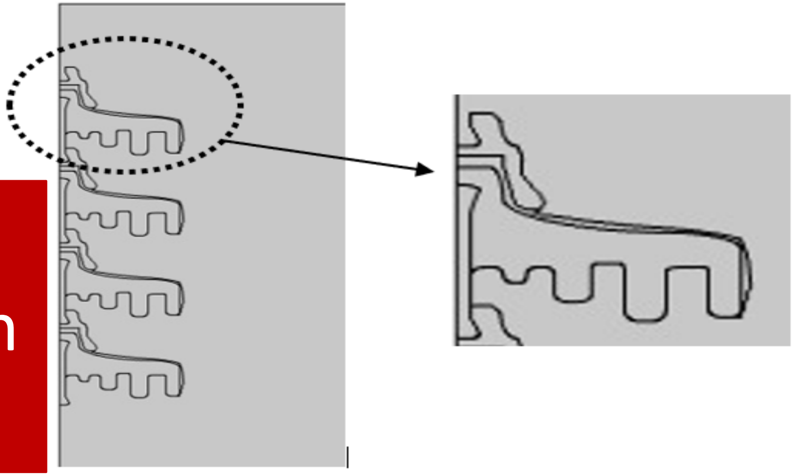
Table 2: *Material properties*

Material	Relative permittivity, (ε_r)	Electric conductivity, (σ)
Glass	4.2	0
Concrete	15	1.0×10^{-4}
Pollution layer (NaCl)	60	Σ
Grading layer (zinc oxide)	12	Σ
Air	1	0
Grading ring (Aluminum)	N/A (conductor)	35.5×10^{-6}

Dry-clean condition model

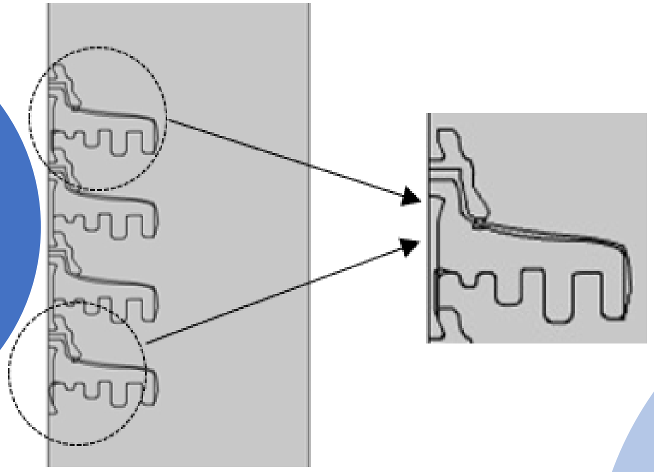


Polluted condition model

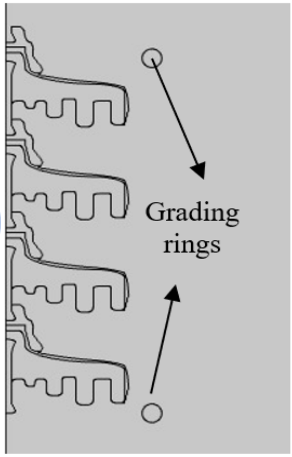


MODELLING TECHNIQUE of Overhead Line Glass Insulator

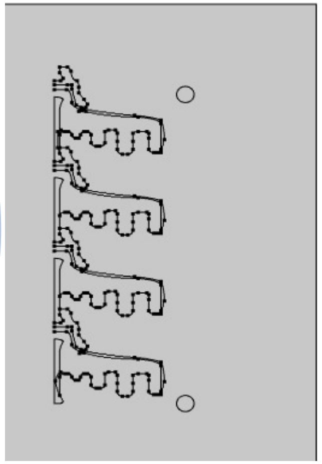
ZnO Micro-Varistor Layer Modelling



Grading Rings Modelling



Combined Technique Modelling



COMPUTATIONAL MODELLING

- Finite element method is performed to analyse the electric field distribution along the insulator surface.
- The mesh element in the areas of interest along the insulator leakage path is manually assigned to enhance the computation efficiency.

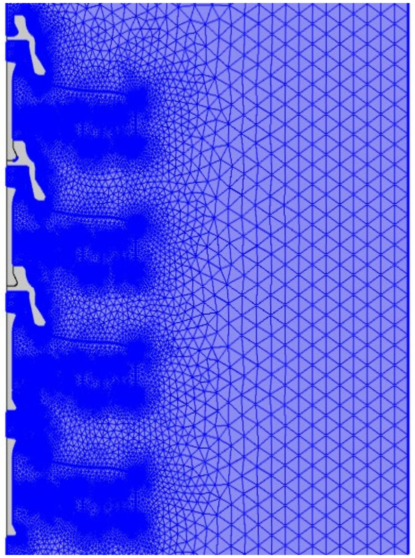


Fig: *Finite element mesh*

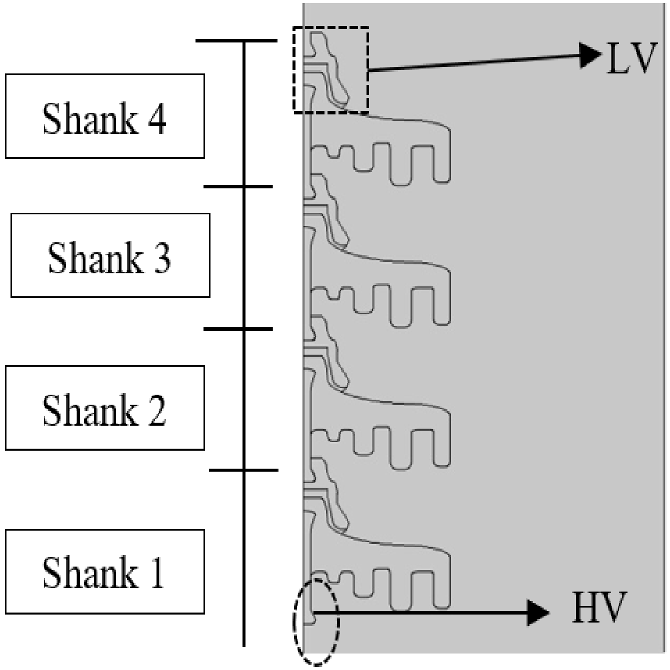


Fig: *Separation of insulator section*

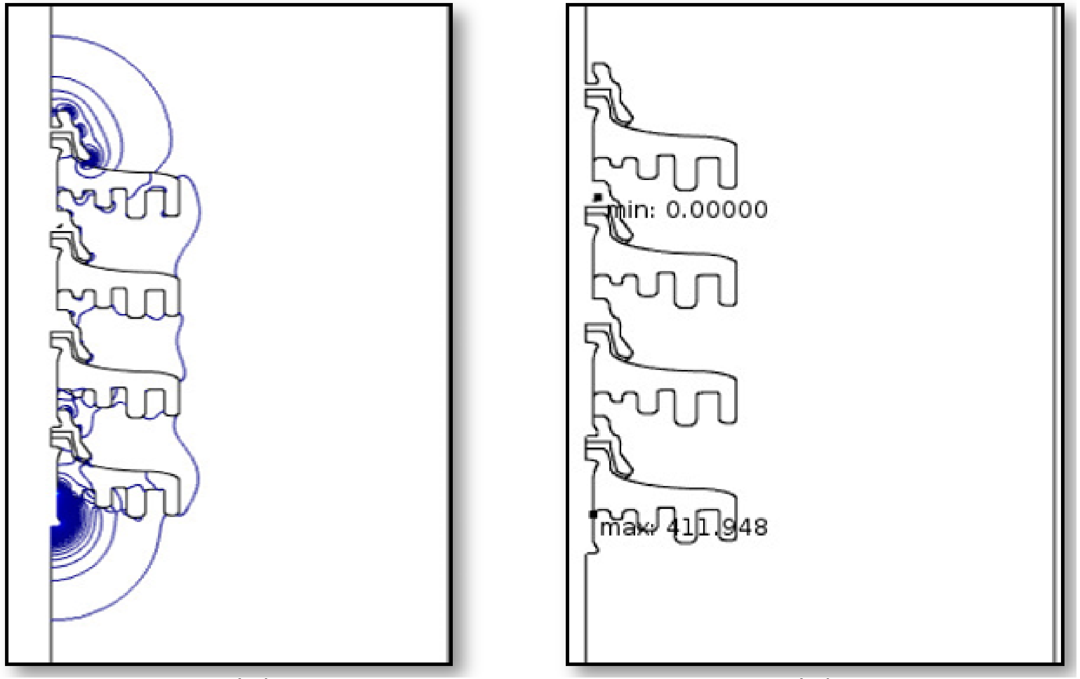
ANALYSIS of Dry-clean Condition

Table 3: *Computed maximum electric field intensity distribution on dry-clean condition*

Surface region	Electric field intensity (kV/cm)
Near HV	194
Shank 1	399.28
Shank 2	4.4
Shank 3	2
Shank 4	1.8
Near LV	12

Shank 1 has drawn the maximum electric field intensity.

The electric field intensity was normally high near the electrode, which in this case that the Shank 1 is the nearest to the high voltage electrode.



(a) (b)

Fig: *Computation of (a) electric field intensity distribution, and (b) maximum electric field intensity on dry-clean condition.*

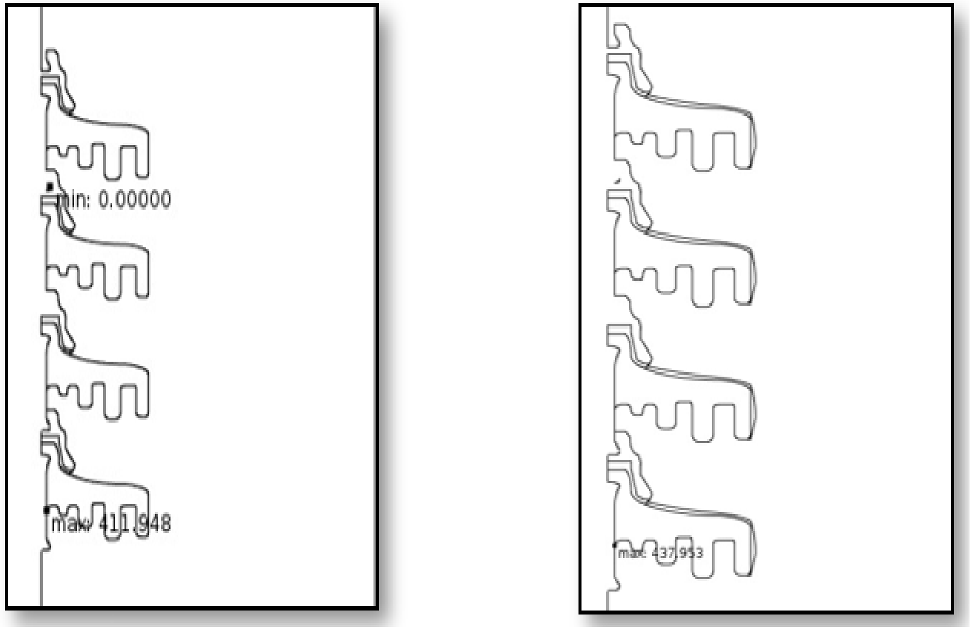
ANALYSIS of Polluted Condition

Table 4: *Computation of electric field intensity distribution on dry-clean condition and polluted condition*

Surface region	Reference data (kV/cm)	Difference (kV/cm)	Polluted condition (kV/cm)
Near HV	194	9.6	203.6
Shank 1	399.28	24.32	423.6
Shank 2	4.4	-3.45	0.95
Shank 3	2	-0.31	1.69
Shank 4	1.8	57.2	59
Near LV	12	10	22

The overall electric field intensity along the insulator profile does increase as the pollution layer affecting the insulator performance.

The enhancement of electric field intensity mainly at the insulator surface was purposely layered with NaCl.



(a) (b)

Fig: *Comparison on maximum electric field intensity for (a) dry-clean condition, and (b) polluted condition.*

EFFECT OF ZnO on Dry-clean and Polluted Condition

Table 5: *Computational of electric field intensity with and without ZnO*

Surface region	Reference data (kV/cm)	Dry-clean with ZnO (kV/cm)	Polluted condition without ZnO (kV/cm)	Polluted condition with ZnO (kV/cm)
Near HV	194	64	203.6	66.3
Shank 1	399.28	117.3	423.6	124.35
Shank 2	4.4	1.1	0.95	0.72
Shank 3	2	2.25	1.69	2.4
Shank 4	1.8	39.4	59	77
Near LV	12	16	22	27.5

- For dry-clean condition, ZnO able to alleviate the electrical stress by 70.6% on Shank 1.
- During polluted condition, with ZnO is being applied, the E_{max} value was recorded at 124.35 kV/cm, which was 70.6% reduction from 423.6 kV/cm without applying ZnO.

EFFECT OF Grading Ring on Dry-clean and Polluted Condition

Table 6: Computational of electric field intensity with and without grading rings

Surface region	Reference data (kV/cm)	Dry-clean with grading rings (kV/cm)	Polluted condition without grading rings (kV/cm)	Polluted condition with grading rings (kV/cm)
Near HV	194	189	203.6	203.15
Shank 1	399.28	388.4	423.6	419.32
Shank 2	4.4	3	0.95	0.0965
Shank 3	2	2	1.69	0.15
Shank 4	1.8	28.4	59	60
Near LV	12	11.8	22	22

- The electric field distribution had improved by 2.7% during dry-clean condition and 1% during the polluted condition when grading rings being applied.
- For polluted condition, this mitigation scheme also shows the same pattern as in dry-clean conditions.
- It was noticed that on Shank 4, the electric field intensity was distributed as it went from 1.8 kV/cm up to 28.4 kV/cm. It shows that the grading rings works not only to alleviate the electrical stress but also redistribute the stress onto the other place along the insulator surface.

EFFECT OF Combined Technique on Dry-clean and Polluted Condition

Table 7: *Computational of electric field intensity with combination technique under dry-clean and polluted condition*

Surface region	Reference data (kV/cm)	Dry-clean with combination technique (kV/cm)	Polluted condition without combination technique (kV/cm)	Polluted condition with combination technique (kV/cm)
Near HV	194	64	203.6	67
Shank 1	399.28	21.8	423.6	121.3
Shank 2	4.4	3	0.95	0.73
Shank 3	2	14.77	1.69	1.9
Shank 4	1.8	36.7	59	77.3
Near LV	12	15.4	22	28.9

- This combined scheme had shown promising results for both, dry-clean and polluted condition.
- The peak magnitudes in the high field regions of the polluted condition, particularly at the HV end were reduced by nearly 67%.
- On average, the electric field distribution had been improved by 58% with this combination technique.

CONCLUSION

The effectiveness of mitigation scheme applied for the electric field intensity stress control along the insulator surface is analysed. The various method had been tested and had shown the performance of the mitigation process. This study is able to identify the likelihood of the location of breakdown and the maximum electric field intensity was determined for each tested condition. The effect of pollution in the form of salt formation had been identified as it does distort the electric field distribution. Therefore, it is recommended for the electric field stress control on an overhead line glass insulator to utilise the combination technique of zinc oxide and grading rings. This technique proved to be effective as it is able to reduce the electric stress on the insulator surface by 84% and works under the polluted condition as well.

Thank You