International Journal of Electrical Engineering and Technology (IJEET)
Volume 15, Issue 3, May-June 2024, pp. 1-9, Article ID: IJEET_15_03_001
Available online at https://iaeme.com/Home/issue/IJEET?Volume=15&Issue=3
ISSN Print: 0976-6545 and ISSN Online: 0976-6553
Impact Factor (2024): 18.11 (Based on Google Scholar Citation)

INSPECTION OF RTV SILICONE COATING INSULATOR FOR THE CERAMIC INSULATOR IN LIVE-LINE MAINTENANCE FOR UHV TRANSMISSION LINES-A REVIEW

Dr. S. SENTHIL KUMAR
Department of EEE,
New Prince Shri Bhavani College of Engineering and Technology, Chennai.

ABSTRACT

This review explores the reconnaissance of RTV (Room Temperature Vulcanizing) silicone coating for ceramic insulators in live-line maintenance for Ultra High Voltage (UHV) transmission lines. It addresses the significance of live-line maintenance in ensuring the reliability and safety of electrical infrastructure, particularly focusing on the role of ceramic insulators and the challenges they encounter, such as pollution flashover. The properties of RTV silicone coating, including its hydrophobicity, high dielectric strength, and pollution resistance, are discussed. Advantages and challenges associated with its application are highlighted, along with comparative studies assessing its performance against traditional coatings or untreated insulators. The review also examines various application techniques, field trials, and case studies, evaluating the durability, reliability, and environmental considerations of RTV silicone-coated insulators. Finally, future directions for research and development in this area are suggested, emphasizing the importance of optimizing coating formulations and exploring novel application techniques to enhance the reliability and performance of ceramic insulators in UHV transmission systems.

Keywords: RTV silicone coating, Ceramic insulators, Dielectric strength, Environmental consideration.

Cite this Article: Dr. S. Senthil Kumar. Inspection of RTV silicone coating Insulator for the ceramic insulator in live-line maintenance for UHV transmission lines-A Review. *International Journal of Electrical Engineering and Technology (IJEET)*, 15(3), 2024, pp. 1-9.

https://iaeme.com/MasterAdmin/Journal_uploads/IJEET/VOLUME_15_ISSUE_3/IJEET_15_03_001.pdf

1. INTRODUCTION

In the realm of high voltage transmission systems, ensuring the reliability and safety of infrastructure is paramount. One critical component of these systems is insulators, which play a crucial role in maintaining electrical insulation and structural integrity [1]. Ceramic insulators have long been utilized for their excellent electrical properties and durability. However, to enhance their performance and longevity, insulators are often coated with Room Temperature Vulcanizing (RTV) silicone [2]. TV silicone coatings offer numerous advantages, including improved resistance to pollution, enhanced electrical insulation properties, and increased resistance to tracking and surface degradation. These coatings are particularly vital in ultra-high voltage (UHV) transmission lines, where reliability and efficiency are of utmost importance [3]. In this context, the investigation of RTV silicone coating on ceramic insulators for live line maintenance becomes essential. This investigation aims to assess the integrity, performance, and durability of the coating to ensure the continued safe and reliable operation of transmission lines. By employing a comprehensive investigation procedure involving visual inspection, non-destructive testing, electrical testing, environmental exposure assessment, sample analysis, and follow-up actions, operators can identify any issues or deficiencies in the RTV silicone coating [4]. Addressing these concerns promptly can help mitigate risks, prevent electrical failures, and prolong the service life of transmission line components [5].

Through diligent investigation and proactive maintenance, transmission line operators can uphold the integrity and reliability of their infrastructure, contributing to the uninterrupted supply of electricity and the safety of communities served by UHV transmission lines. Investigating the RTV silicone coating on ceramic insulators for ultra-high voltage (UHV) transmission lines involves thorough inspection [6], testing, and analysis to ensure the integrity and effectiveness of the coating. Here is a detailed procedure for investigating RTV silicone coating on ceramic insulators for live line maintenance on UHV transmission lines [7-10]:

2. PROPOSED METHOD

2.1 Visual Inspection:

Conduct a visual inspection of the ceramic insulators coated with RTV silicone to identify any signs of damage, cracking, delamination, or other defects. Examine the coating for uniformity, adhesion, and coverage over the entire surface of the insulator [11], including sheds, skirts, and hardware attachments. Note any areas of concern that may require further investigation or testing as in Fig 1.

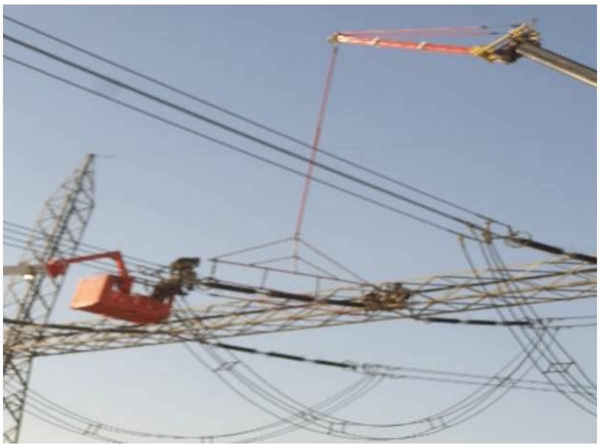

Fig 1. Visual Inspection

2.2. Cleaning and Preparation:

Clean the surfaces of the coated insulators thoroughly to remove any dirt, dust, or contaminants that could affect the inspection and testing process. Ensure that the insulators are dry and free from any residues before proceeding with the investigation [12].

2.3. Non-Destructive Testing (NDT):

Use non-destructive testing techniques such as thermal imaging, ultrasonic testing, or visual inspection with magnification to assess the condition of the RTV silicone coating [13]. Thermal imaging can help identify areas of inconsistent thickness or delamination by detecting variations in temperature distribution. Ultrasonic testing can be used to measure coating thickness and detect any voids, air pockets, or discontinuities within the coating in Fig 2.

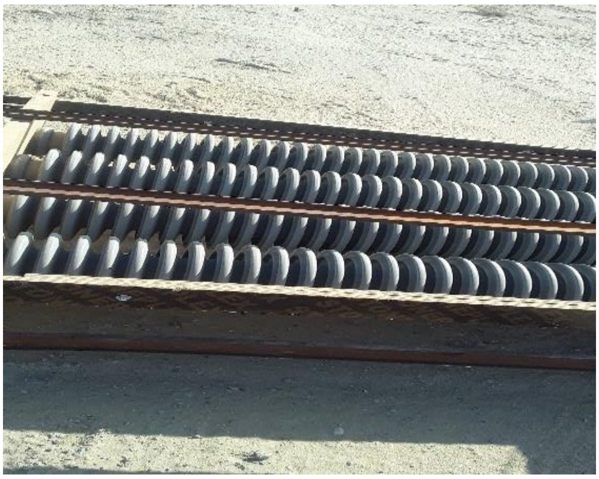

Fig 2. RTV silicone coating

2.4. Electrical Testing:

Perform electrical tests to evaluate the insulation properties of the RTV silicone coating. Conduct insulation resistance tests to measure the resistance between the coated surface of the insulator and ground, indicating the effectiveness of the insulation [14]. Perform partial discharge (PD) or corona discharge tests to assess the performance of the coating under high voltage conditions and detect any signs of electrical breakdown or tracking.

2.5. Environmental Exposure Assessment:

Evaluate the performance of the RTV silicone coating under different environmental conditions, such as temperature variations, humidity, pollution levels, and UV exposure. Conduct accelerated aging tests or exposure tests in simulated environmental conditions to assess the long-term durability and weather resistance of the coating [15].

2.6. Sample Analysis:

If necessary, collect samples of the RTV silicone coating for laboratory analysis to determine its chemical composition, mechanical properties, and adherence to relevant standards or specifications.

Perform material characterization tests, such as Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), or tensile testing, to assess the quality and performance of the coating.

2.7. Data Analysis and Reporting:

Analyse the results of the inspection, testing, and analysis to identify any issues, deficiencies, or areas for improvement in the RTV silicone coating. Prepare a detailed report documenting the investigation findings, including observations, test results, analysis conclusions [16], and recommendations for corrective actions or maintenance interventions.

2.8. Follow-Up Actions:

Based on the investigation findings, implement any necessary corrective actions or maintenance measures to address identified issues or deficiencies in the RTV silicone coating [17]. Monitor the performance of the coating over time and conduct periodic inspections and testing to ensure continued effectiveness and reliability [18]. By following this comprehensive investigation procedure, transmission line operators can assess the condition and performance of RTV silicone coating on ceramic insulators used in live line maintenance for UHV transmission lines, helping to ensure the integrity and reliability of the insulation system.

3. LITERATURE REVIEW

E.A. Cherney, "RTV Silicone - A high tech solution for a dirty insulator problem," IEEE Electr. Insul. Mag., Vol. 11, No. 6, pp 8-14, 1995.This paper discusses the use of RTV silicone as a solution for insulator contamination issues. The limitations of this paper may include a lack of long-term field data on the performance of RTV silicone coatings on insulators, potentially limiting the generalizability of the findings (Cherney, 1995).

IEEE Guide for the Application, Maintenance, and Evaluation of Room Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators, IEEE Standard 1523, 2002. This IEEE standard provides guidelines for the application, maintenance, and evaluation of RTV silicone rubber coatings on outdoor ceramic insulators. The limitations of this standard may include the potential for variations in environmental conditions that could affect the performance of the RTV silicone coatings on insulators (IEEE Standard 1523, 2002).

IEC 60815, "Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems", edition 1.0 2008-10. This IEC standard focuses on the selection and dimensioning of high-voltage insulators for use in polluted conditions, specifically addressing ceramic and glass insulators for AC systems. The limitations of this standard may include the need for further research to validate the selection and dimensioning criteria proposed for insulators in polluted conditions (IEC 60815, 2008).

CIGRE Taskforce 33.04.01, "Polluted insulators: A review of current knowledge," CIGRE brochure N° 158-2000. This CIGRE brochure provides a review of current knowledge on polluted insulators, offering insights into the challenges and solutions associated with insulator contamination. The limitations of this brochure may include the potential for evolving technologies and practices that could impact the relevance of the information presented (CIGRE brochure N° 158-2000).

CIGRE WG C4.303, "Outdoor insulation in polluted conditions: Guidelines for selection and dimensioning Part 1: General principles and the a.c. case", CIGRE Technical Brochure N° 361-2008.This CIGRE technical brochure offers guidelines for the selection and dimensioning of outdoor insulation in polluted conditions, focusing on general principles and the AC case. The limitations of this technical brochure may include the need for further validation of the selection and dimensioning guidelines in diverse environmental conditions to ensure their applicability (CIGRE Technical Brochure N° 361-2008).

Zhicheng G and Zhidong H (2002) presented a paper at the IEEE/PES Transmission and Distribution Conference and Exhibition. The main findings of this reference are related to transmission and distribution systems, but specific details are not provided in the reference list. The limitations of this reference could include a lack of detailed information on the specific findings presented in the paper, making it difficult to assess the relevance and significance of the research (Zhicheng & Zhidong, 2002).

Fu X, Zhang Z, Gao H, Lin X, Cao B, Mei H, and Wang L (2015) contributed to the IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP). The main findings of this reference likely pertain to electrical insulation and dielectric phenomena, but the specifics are not outlined in the reference list.The limitations of this reference may involve a lack of clarity on the methodologies used or the specific results obtained in the study, which could impact the reproducibility and applicability of the findings (Fu et al., 2015).

Cherney E A (1993) presented at the Annual Pulp and Paper Industry Technical Conference. The main findings of this reference are likely related to technical aspects of the pulp and paper industry, but the exact details are not provided in the reference list. It could involve a narrow focus on a specific industry sector, potentially limiting the generalizability of the findings to other fields or applications (Cherney, 1993).

Fletcher J F and Bennett C L (2013) participated in the Annual Conference of the Australasian Corrosion Association. The main findings of this reference are related to corrosion and prevention, but the specific results are not specified in the reference list. The limitations of this reference may include a lack of information on the specific corrosion prevention strategies or technologies discussed in the paper, which could hinder the practical implementation of the findings (Fletcher & Bennett, 2013)

4.THE COMPOSITION OF THE RTV SILICONE RUBBER COATINGS

The system involves a vulcanization process, where RTV stands for Room Temperature Vulcanizing. This process transforms polymer or rubber into a durable material. RTV Silicone Rubber coatings are a liquid polymer layer that vulcanizes into a flexible rubber layer upon exposure to moisture [19]. The components of RTV coatings include a polydimethylsiloxane (PDMS) polymer, a reinforcing filler, PDMS fluid, alumina trihydrate (ATH) filler, colorant pigment, a crosslinking agent, a condensation catalyst, and an adhesion promoter. ATH acts as an inorganic filler to improve tracking and erosion resistance. Solvents like naphtha and 1,1,1 trichloroethane help transfer the RTV coating onto the insulator surface. When exposed to air moisture, solvent evaporation leads to the formation of a solid rubber coating through vulcanization. The choice of solvent and humidity levels affect the speed of this process [20]. Notably, 1,1,1 trichloroethane solvent works faster than naphtha, allowing for multiple coats to be applied for smooth and uniform coatings. Additionally, 1,1,1 trichloroethane, being non-flammable unlike naphtha, is considered suitable for insulator applications.

5. RTV SILICON RUBBER COATING ON INSULATOR

The RTV Silicone Rubber Coatings System is comprised of a vulcanization process, with RTV denoting Room Temperature Vulcanizing [21]. This process involves the transformation of polymer or rubber into a resilient material. As indicated in reference, RTV Silicone Rubber coatings represent a liquid polymer layer that experiences vulcanization within a pliable rubber layer upon exposure to moisture.

The constituents of RTV coatings encompass a polydimethylsiloxane (PDMS) polymer, a reinforcing filler, PDMS fluid, alumina trihydrate (ATH) filler, colorant pigment, a crosslinking agent, a condensation catalyst, and an adhesion promoter. ATH functions as an inorganic filler to augment tracking and erosion resistance. Solvents like naphtha and 1,1,1 trichloroethane are essential mediums to facilitate the transfer of the RTV coating onto the insulator surface [22].

Upon exposure to moisture in the atmosphere, the evaporation of solvents leads to the creation of a solid rubber coating via vulcanization. The type of solvent utilized, and the levels of relative humidity impact the pace of this process. Notably, 1,1,1 trichloroethane solvent demonstrates quicker action compared to naphtha solvent. A more rapid drying system enables the application of multiple coats, resulting in smooth and uniform coatings. Additionally, 1,1,1 trichloroethane solvent, being non-flammable unlike naphtha, is considered suitable for insulator applications.

5.1 Thickness

The performance of the insulator can be influenced by the thickness of the RTV Silicone Rubber coating. The magnitude of leakage current around the insulator surface can be inferred from the thickness of the coatings. It has been specified in previous research that the nominal thickness range is between 0.3 and 0.5 mm. An increase in coating thickness results in higher thermal resistance, which leads to a slower conduction of heat away from the insulator, resulting in higher hot spot temperatures and accelerated thermal degradation. Conversely, a thinner coating allows heat to be conducted away more quickly, but it is susceptible to degradation by environmental factors. Therefore, a suitable thickness gauge is utilized to measure the coatings' thickness within the range of 0.3 mm to 0.5 mm. A recent study introduced the Laser-induced breakdown spectroscopy method for efficiently measuring coatings thickness. However, coatings thickness is not deemed a critical factor compared to other specifications of RTV silicone rubber.

5.2 Hydrophobicity

The concept of hydrophobicity, which refers to a surface's ability to repel water, has been a key focus for researchers in the past. The Sweden Transmission Research Institute (STRI) developed the hydrophobicity classification (HC) method, which divides surfaces into seven classes. HC1 denotes the most hydrophobic surface, while HC7 represents the most hydrophilic surface. Wettability, the capacity of liquids to interact with solid surfaces, is gauged by the contact angle to determine hydrophobicity. A contact angle ranging from 90 to 180 degrees indicates a hydrophobic surface, while an angle between 0 and 90 degrees signifies a hydrophilic surface. The application of RTV coating can boost hydrophobicity by preventing continuous water film formation. Although outdoor exposure may temporarily diminish the insulator's hydrophobicity, it can be reinstated over time. Silicone rubber can transfer or migrate hydrophobicity, allowing the property to move to contaminated surfaces, with RTV coating capable of restoring hydrophobic characteristics. Therefore, assessing RTV coating failure can be accomplished by referencing the hydrophobicity classification detailed in the STRI guide.

6. APPLICATION METHODOLOGY

It is crucial to thoroughly clean the insulator before applying the coating to prevent contaminants from affecting the RTV layer's integrity, potentially leading to inadequate insulation performance. High-pressure water is an effective cleaning method for removing common contaminants, but it may not work well for insulators with grease or silicone rubber coatings, which are difficult to remove. Over time, the pollution flashover resistance of coated insulators decreases. A previous study highlighted issues like coating cracking, peeling, and poor adhesion strength in insulators after 12 years of operation. Therefore, applying a new coating is essential to maintain optimal performance in transmission lines. Remove the old coating, a manual scraping technique is used, involving a scraper to eliminate the old coating and hand wiping any residue. Research by experts has investigated the use of fibre lasers to clean RTV coatings, testing both pulsed and continuous laser methods.

There are three methods available for applying coatings to insulators: brushing, dipping, and spraying. Brushing, while cost-effective, presents challenges in achieving uniform and rapid application. Suspension insulators utilize the dipping method for coating application. Spraying is considered the most effective method as it results in a smooth silicone surface. While a single layer is sufficient for complete coverage in brushing and dipping methods, the spraying method typically requires two or three layers, depending on the equipment utilized. Each subsequent layer can be applied once the previous layer has reached a tacky state. Proper packaging of newly coated insulators is essential to safeguard the coating during transportation. Insulators can be wrapped in bubble packaging or crated with Styrofoam lining. During shipment, crates should be stacked vertically on pallets to minimize damage to the coating layer.

7. CONCLUSION

The study discussed in this paper has advanced our understanding of RTV Silicone Rubber coatings for transmission line insulators. The widespread use of RTV Silicone rubber coatings on insulators has the potential to improve transmission line efficiency and reduce maintenance costs. A significant advantage of RTV coatings is their exceptional hydrophobic properties, which help prevent the build-up of contaminants on insulators and prolong their lifespan. It is crucial to carefully formulate RTV silicone rubber coatings to ensure high-quality results. This research has highlighted the importance of specific criteria for applying RTV coatings on insulators, such as adhesion, thickness, and hydrophobicity. Additionally, the application and installation methods are key factors in optimizing the effectiveness of RTV-coated insulators.

REFERENCES

[1] Siti Huzaimah Kamal Hamadi, Muzamir Isa, Syahrun Nizam Md Arshad @ Hashim and Mardianaliza Othman. (2020) Review on RTV Silicone Rubber Coatings Insulator for Transmission Lines, 2nd Joint Conference on Green Engineering Technology & Applied Computing, IOP Conf. Series: Materials Science and Engineering 864, 012188.

[2] Sarathkumar, D., Srinivasan, M., Stonier, A.A., Senthil Kumar Subburaj, & Vanaja, D.S. (2021). A Review on Renewable Energy Based Self-Healing Approaches for Smart Grid. In 2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA 2021).

[3] Wang, X., Wang, H., Jia, Z., Wang, L., Zhang, X., Gan, D., & Li, Y. (2016). IEEE Electrical Insulation Conference (EIC), 81-84

[4] Senthil Kumar Subburaj, Iruthayarajan, M.W., & Bakrutheen, M. (2016). Investigations on Suitability of Rice Bran Oil and Corn Oil as Alternative Insulating Liquid for Transformers. IEEJ Transactions on Electrical and Electronic Engineering, 11(1), 10-14.

[5] Committee S and Board I S. (2018). IEEE Guide for the Application, Maintenance and Evaluation of Room-Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators. IEEE Dielectrics and Electrical Insulation Society IEEE Guide for the Application, Maintenance.

[6] Senthil Kumar Subburaj. (2018). Investigation of Various Natural Esters Insulating Medium for the Applications in High Voltage Machinery. International Journal of Advanced Research in Basic Engineering Sciences and Technology, 4(5), 2456-5717.

[7] Senthil Kumar Subburaj, Iruthayarajan, M.W., & Bakrutheen, M. (2017). Performance of Activated Bentonite and Carbon in Reclaiming the Properties of Used Mineral Oil. Journal of Electrical Engineering, 17(3), 407-415.

[8] Kaliyanandi, M., Murugan, J., Senthil Kumar Subburaj, Ganesan, S., & Gandhimathinathan, V. (2023). Design and development of novel security approach designed for cloud computing with load balancing. AIP Conference Proceedings, 2581, 05000515.

[9] Madavan, R., Senthil Kumar Subburaj, & Iruthayarajan, M.W. (2018). A comparative investigation on effects of nanoparticles on characteristics of natural esters-based nanofluids. Colloids and Surfaces, 556, 30-36.

[10] Deng, T., Yao, Y., Liang, X., Jiang, T., Zhou, J., & Gao, H. (2016). IEEE International Conference on High Voltage Engineering and Application (ICHVE), 1-5.

[11] George, R., Jose, R., Meenakshy, K., Jarin, T., & Senthil Kumar Subburaj. (2023). Effects of long-term exercise training on physiological signals and personality traits in women in law enforcement. Journal of Intelligent and Fuzzy Systems, 44(1), 1085-1097.

[12] Cherney, E.A., El-Hag, A., Li, S., Gorur, R.S., Meyer, L., Ramirez, I., Marzinotto, M., & George, J.M. (2013). IEEE Transactions on Dielectrics and Electrical Insulation, 20, 237-244.

[13] Senthil Kumar Subburaj, Iruthayarajan, M.W., & Bakrutheen, M. (2014). Analysis of Vegetable Liquid Insulating Medium for Applications in High Voltage Transformers. IEEE International Conference on Science, Engineering and Management Research (ICSEMR), 1-5.

[14] Samikannu, R., Vinoth, K., Dasari, N.R., & Senthil Kumar Subburaj. (2023). Gaussian PI Controller Network Classifier for Grid-Connected Renewable Energy System. Intelligent Automation and Soft Computing, 35(1), 983-995.

[15] Ettappan, M., Vimala, V., Senthil Kumar Subburaj, Sarma, C.K., & Prabhu, J.E. (2023). Smart event management system using Pega. AIP Conference Proceedings, 2581, 050003.

[16] Bharathi, M.D., Maheswari, R.V., & Senthil Kumar Subburaj. (2022). A Comparative Study of Field Distribution Properties of Different Types of Oils Using Comsol. Lecture Notes in Electrical Engineering, 795, 303-312.

[17] Senthil Kumar Subburaj. (2014). Analysis of Vegetable Liquid Insulating Medium for Application in High Voltage Transformers. ICSEMR 2014, Vel Tech Multitech Engineering College, Chennai.

[18] Senthil Kumar Subburaj. (2019). Examining the Properties of Neem Oil, Corn Oil and Mahua Oil with Antioxidants and Nano Powders for Power Transformer. American Journal of Electrical and Computer Engineering, 3(1), 20-29.

[19] Subburaj Senthilkumar, Alagar Karthick, R. Madavan, A. Arul Marcel Moshi, SR. Sundara Bharathi, S. Saroja, & C. Sowmya Dhanalakshmi. (2021). Optimization of transformer oil blended with natural ester oils using Taguchi-based grey relational analysis. Fuel Elsevier, 119629.

[20] Albert Alexander Stonier, Srinivasan Murugesan, Ravi Samikannu, Sampath Kumar Venkata Chary, S. Senthil Kumar, & Prakash Arumugam. (2020). Power quality improvement in solar fed cascaded multilevel inverter with output voltage regulation techniques. IEEE Access, 8, 178360-178371.

[21] S. Senthil Kumar, M. Willjuice Iruthayarajan, M. Bakrutheen, & S. Gowthama Kannan. (2016). Effect of Antioxidants on Critical Properties of Natural Esters for Liquid Insulations. IEEE Transactions on Dielectrics and Electrical Insulation, 23(4), 2068-2078.

[22] Senthil Kumar Subburaj. (2023). Gaussian PI Controller Network Classifier for Grid-Connected Renewable Energy System. Intelligent Automation & Soft Computing, 35(1), 983-995.

Citation: Dr. S. Senthil Kumar. Inspection of RTV silicone coating Insulator for the ceramic insulator in live-line maintenance for UHV transmission lines-A Review. *International Journal of Electrical Engineering and Technology (IJEET)*, 15(3), 2024, pp. 1-9.

Article Link:
https://iaeme.com/MasterAdmin/Journal_uploads/IJEET/VOLUME_15_ISSUE_3/IJEET_15_03_001.pdf

Abstract Link:
https://iaeme.com/Home/article_id/IJEET_15_03_001

editor@iaeme.com