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Impact of Pollution on High Voltage Insulators: Research Status and Recommendations

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Abstract— Fast urbanization and industrialization in India over most recent two decades has brought about expanded interest for dependable electric power. The unwavering quality thus is enormously affected by the grid system and its segments being legitimately kept up. One of the imperative parts is the high voltage insulators utilized as a part of the switchyards, overhead lines, substations and power stations. The seriousness of defilement on the high voltage insulator surfaces is the huge consider deciding the level of open air protection and in picking the sorts of insulators. The contamination flashover saw on encasings utilized as a part of high voltage transmission, is a standout amongst the most vital issues for power transmission. Control blackouts because of contaminated encasings that results in flashover are a costly issue: control supply unwavering quality is lessened, industry endures creation downtime and the cost to repair flashover harm is high. Keeping up the cleanliness of insulators through rehashed upkeep is likewise an expensive work out. This review additionally exhibits a combine cleaning technique to keep from tidy amassing on the surface of insulators. This paper also provides an assessment on the modern eminence of research in studying the impact of dust on insulator recital and specifies obstacles to further relatable research. A structure to appreciatethe assortment of factors that rule the settling/amalgamation of dust and probablealleviationprocess have been examined in this paper.

Index Terms— Insulators, flashover, leakage current, pollution.

1 Introduction

THe heft of energy conveyance from generating plant to load centres is transported by overhead lines [1]. The stimulated high voltage line conductors not just must be physically joined to the bolster structures additionally electrically secluded from the bolster structures. The device used to play out the dual utility of support and electrical detachment is the outside high voltage encasing (insulators).
The most key segment that chooses the physical estimations of outside encasings is their execution under tainting conditions. Dependent upon the pollution earnestness and the wetting conditions of the site, outside spreads require satisfactory surface leakage length to ensure that dry band advancement and surface arcing is restricted.

Many years of in-service execution have shown that ceramic insulators, made of porcelain and glass, demonstrate great execution and oppose ecological maturing. Furthermore to upsurge mechanical quality, they give incredible imperviousness to material degradation brought on by electrical anxiety and discharge activities [2]. In any case, they experience the ill effects of having hydrophilic surface properties, which implies that water can undoubtedly shape a constant conductive film along the creepage way, in this manner permitting high surface leakage currents to stream on their wetted surfaces. Such currents cause dry bands at zones of high current density and lower wetting rates, which in the long run cause surface arcing and frequently finishes flashover of the encasing.

Amid late decades, polymer insulators have been presented and generally utilized at distribution voltage levels because of their better contamination execution. Right now, encasings made of polymeric materials are frequently called composite or non-ceramic encasings. Non–ceramic encasings, for example, silicone rubber, offer a few focal points over porcelain encasings. They have excellent hydrophobic (water-repellent) surface properties under wet conditions; this property limits the leakage current and the likelihood of dry band enlargement.Additionally, they have high mechanical strength to weight proportion, resistance against vandalism, and decreased upkeep costs [3]. Nevertheless, polymer materials have weaker silicone to oxygen (Si-O) bonds than porcelain materials so they are more vulnerable to chemical degradation under the various anxieties prone to be experienced in service; including stress because of high functioning voltages, UV rays and contamination sullying.

Corona and electrical discharge can likewise bring about auxiliary issues, for example, capable of being audible noise and electromagnetic interferences. Electrical discharge create steady humming sounds, and the high-recurrence electromagnetic wave from the release can bring about unsettling influences in radio, TV and other communication signals [4]. Under these anxieties, the hydrophobicity on the surface of polymer weathersheds will be briefly or lost [5] after which the encasings will be feeble against flashover.

The contamination flashover execution of an insulator relies upon the sort of contamination store, properties of the insulator material and the wetting states of the site. Flashover of an insulator brings about loss of energy supplied and may harm equipment and produce obliteration of the insulator itself. The contamination sort and its seriousness are subjected to nature. In this setting of contamination impacts, rain can have a common washing impact on the contamination layer before it has collected to a substantial level.

A framework to understand the various factors that govern the settling/assimilation of dust is illustrated in Fig. 1. Therefore, to enhance porcelain insulator performance under dirtied conditions, coatings were utilized to alleviate surface leakage current, surface discharge and diminish flashover event on existing and installed porcelain insulators. This practice is especially appropriate for insulators installed at substations with contamination harshness.

Open air encasings work under various working conditions. Under dry conditions, contaminants don't represent a risk as they are not conductive. Nonetheless, under wet working con-

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ditions, contaminants may disintegrate to shape a conductive layer. This layer can enhance leakage current on the surface of the encasing. Beneath voltage stress, this current leads to heating and drying of the contamination layer. This procedure generates dry regions over the surface called dry bands. A breakdown will occur in the presence of concentrated electric field stress in the dry band region. Partial arcs over the surface starts to arise when the voltage gradient across the dry band regions exceeds the dry bands withstand capabilities. If this arc propagates across the layer of contaminants which bridges the surface distance of the insulator, a flashover will transpire [6].

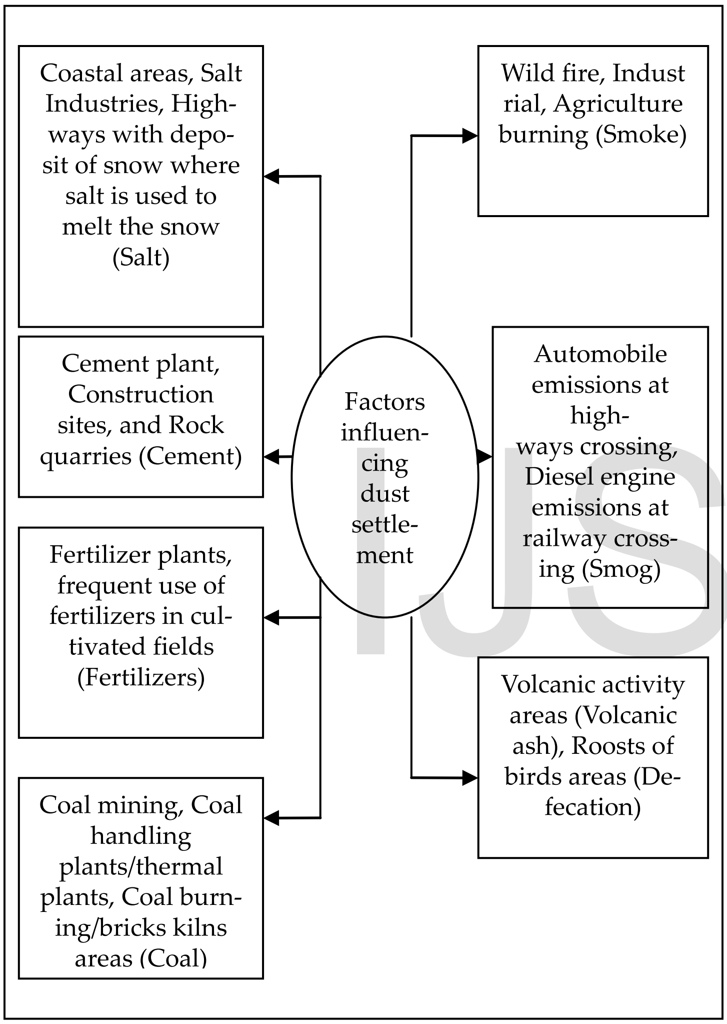

Fig. 1 Factors influencing dust settlement on high voltage insulators.

Flashover may harm the insulator incidentally or forever and may bring about an interference of the power supply contingent upon its seriousness [7]. Polymers, similar to silicone rubber and ethylenepropylene–diene monomer (EPDM) are hydrophobic materials and can stifle the leakage current considerably in a more productive way than porcelain materials. This property makes the defilement flashover execution of the polymer much superior to flashover execution of the porcelain [8].

Numerous papers have attempted to study the phenomenon of dust settlement and general recommendations to mitigate the dust settlement on high voltage insulators in the context of insulators.

2 Pollution Flashover

The pollution flashover process for ceramic was described by CIGRE working group 33.04 [9] as follows:

1. There are two cases for insulators tainted with a layer of contamination containing solvent salts or weaken acids or alkalis, if the contamination is wet in a type of a fluid electrolyte, steps 3 to 6 may continue instantly though for the instance of a dry non-conductive layer, a procedure of layer wetting portrayed in step 2 is crucial.
2. Under wet ecological conditions, for example, haze, fog light rain, hail or melting snow or ice, the contamination layer ends up noticeably wet, either totally or partially, and consequently conductive. Substantial precipitation might be valuable by washing off the contamination from the insulator surface, or it could lead straightforwardly to flashover.
3. Under energisation, a surface leakage current begins to stream on the surface of the insulator which dries out parts of the wet layer because of the present warming impact.
4. Inconsistent drying of the wet layer brings about the development of dry zones, called dry-bands, which might be just a few centimetres in width. These areas intrude on the stream of current on the contamination layer.
5. The stimulated voltage applied over the dry-bands makes the conditions for the air breakdown, and the dry-bands are spanned by surface discharges which are electrically in arrangement with the resistance of the wet contamination layer. Quick present pulses are related with the spreading over of dry-bands by discharges.
6. On the off chance that the resistance of the wet contamination layer is sufficiently low, the dry-band discharges stay dynamic and progressively longer segments of the insulator are spread over. This thus brings about a further lessening in the wet layer resistance, builds the current and permits the arcs to connect significantly a greater amount of the insulator surface, lastly in total flashover of the insulator. The whole process described above is shown in Figure 2.

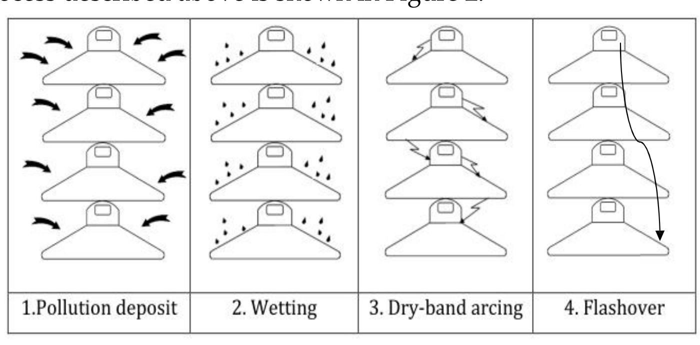

Fig. 2 Main stages of contamination flashover on ceramic insulators [2.8]

3 Belongings Maintenance Plans of Pollutants and Protective Coatings on High Voltage Insulators

Tsai et al., [10] carried out a study on cleaning of standard type high voltage outdoor insulators by air particle spray. This study clearly demonstrates the degree of contaminant removal is determined not only by particle mass flow rate but also particle velocity. Corn cob particles, even at smaller mass flow rates, are more effective than walnut shell particles. Gorur et al., [11] stated that the soiling of in-service electrical insulators exposed to the atmosphere is a major problem in power transmission lines. It is produced by deposition of particles from air which can be natural or generated by artificial pollution as a result of industrial, agricultural or construction activities. Goto et al., [12] suggested common preventive maintenance plans which include water washing as the most used alternative. In sites with high pollution deposition, the insulator washing is expensive and requires much manpower and water. Gorur et al., [13] suggested some other methods which involve the application of silicones or grease on the insulator surface before being put into service.

This alternative was found to be expensive, but its main disadvantage is that it gradually lose their dielectric and viscosity properties, and for that, it is necessary to remove and reapply the coating. Robert et al., [14] studied the biological contaminants on high voltage porcelain insulators, showed a dried algae on an insulator leave a thin oil or waxy film on the surface of the glaze which results the hydrophobic regions they leave are also unevenly distributed leaving regions of differing electrical stress when wetted by rain, fog or dew.A 'dry band' situation may form allowing the generation of corona and scintillation. The etching of insulator glaze by algae may take considerable time. When the covering algae dies or is removed, the exposed etched surface will allow for the origination of arching and corona as it presents many fine points. Montoya-Rena et al., [15] found that the frequency of removing and reapplying the coating can vary from month to several years, depending on the type and level of contamination and the environmental conditions. Ayman et al., [16] demonstrated the effect of insulator profile on ageing performance of silicone rubber insulators in salt-fog. They demonstrated that dry band arcing is a main electrical cause for ageing in insulators, but it is substantially possible to reduce this by modifying the insulator profile as an alternating diameter shed design with small shed spacing, or selective protection to the regions that are prone to dry band activity by cup shaped sheds, the insulators perform significantly better than the commonly used straight shed designs. Another solution is related with the insulation coordination, in which the Basic Insulation Level (BIL) of the transmission line can be oversizing to increase the withstand voltage stress and the leakage path length on the insulation to reduce flashover probability or just modifying their insulator geometry to reduce the particles deposition. However, this procedure is restricted by tower dimensions by IEC group [17].

Gencoglu et al., [18] said that rain does not always clean the insulator surface, especially under strong marine or industrial pollution, or when rain is not regular enough. The accumulation of particles on the insulator surface mixed with moisture conditions can reduce the dielectric properties of insulators and increase the leakage currents. Xingliang et al., [19] studied the comparison of DC pollution flashover performances of various types of porcelain, glass, and composite insulators, which gave the results as the flashover voltage gradients of composite insulators are higher than those of porcelain or glass ones. With the increase of salt deposition density, the effectiveness of leakage distance of the composite insulators will increase and that of the porcelain and glass insulators will decrease. Haddad et al., [20] showed the major cause of insulator rupture at nominal voltage. They also defined the flashover as the dielectric breakdown of air in the vicinity of the insulator surface, initial discharge generally occurs in the air, because it has a comparatively low dielectric strength. Montoya-Tena et al., [21] showed the failures in outdoor insulation caused by bird excrement. Huafeng et al., [22] has concluded that the high salt deposit on the insulators resulted from peculiar terrain and the dampening effect on hydrophobicity transfer characteristic of silicone composite material lower the flashover voltage of silicone composite insulators and ceramic or glass insulators with RTV coatings leading to severe partial discharge activity and flashovers during winter.

Boudissa et al., [23] presented pollution distribution on insulators is non-uniform due to their shape and their position in-service, weather conditions and the action of electric field. Boudissa et al., [23] showed the effect of pollution distribution class on insulator flashover under AC voltage, where they described contribution of three major categories of non-uniform pollution distribution on real insulators surface namely: traversal which is due to the wind and rain directions, longitudinal periodic which is governed by aerodynamic shape of sheds and natural washing of their upper surfaces by rain and longitudinal non-periodic is mainly generated by the electric field attracting pollutant deposits on the partial surface of insulators situated besides the phase conductor or by insulator position in the chain such as in the case of string insulator in star or in T configuration. Defensive coatings are applied to insulators to upgrade their hydrophobic surface properties. A capable defensive covering for limiting the improvement of surface water films must be water-repellent, with the true objective that a degraded separator shows a high resistance with low leakage current and dry band arcing [24, 25, 26, 27]. Numerous coatings have been utilized on ceramic insulators, for example, waxes, paints, veneers and lacquers. In any case, their utilization is restricted as a result of concerns about their long haul performance. These coatings tend to wet-out as effortlessly as ordinary porcelain insulators, furthermore, may likewise harmed by corona discharges. These coatings fluently loss their hydrophobicity when presented to ecological anxieties, for example, corona discharges and UV. At the point when hydrophobicity is lost they wet-out as ordinary porcelain insulator and presented to flashovers. Moreover, paints and polishes don't really demonstrate great hydrophobic surface properties as they wet as effortlessly as ceramic insulators and seem to be, consequently, subject to weathering stresses and effortlessly harmed by corona discharges [28].

Acceptable insulators to fight contamination flashover have been utilized with oil baths. An oil surface is almost un-pollutable, as all solid particles are mixed with the oil. It is manufactured using pedestal-post and weathershield and also cap-and-pin and pin-type constructions. By the effect of the wind and due to the tendency of oil to creep, these are deposited on the lowest insulator string surface. The whole surface of the insulator becomes roofed with oil and shows a very high resistance to the flow of leakage current. As oil creeps over the rest of the surface, soaks the solid pollution and render it as water-repellent. Therefore, the pollution performance of this type of insulator has been very satisfactory. Polluted oil (when the oil becomes polluted with water and dirt) should be replaced with the new oil. Wind is a major cause of oil loss and insulators, with small baths or when the oil baths are inadequately protected from rain and wind, need recurrent checking and refilling [29]. Service experience with oil-bath post insulators at enormously contaminated sites has been quite decent, but there have been some flashovers. Intricacy of profile makes their manufacturing tremendously difficult and this is considered as their key disadvantage as the oil was blown out of the reservoir and was hard to sufficiently protect the oil paths from rain and wind [30]. Flashover would be easily avoidable if a fairly uniform voltage distribution could be sustained over an insulator surface under all conditions.

However, the voltage distribution on a porcelain insulator becomes non-uniform under wet operating conditions because of the wetted pollution layer on its surface, consequently surface discharges and perhaps complete surface flashover may arise [31]. This exertion can be overwhelmed if the insulator is subdivided into a number of segments and each segment paralleled with an appropriate fixed resistance. There are numerous methods in which the fixed resistances can be assimilated in the insulator; nonetheless one of the most eye-catching approaches is to coat the porcelain with a glaze having the required resistance. Glazes entail mostly of glass comprising of small proportion of tin oxide particles. Approximately the width of the glassy layer was 4 μm, although its resistivity was found to be in the order of 108- 109 Ω-m. The glaze allows a small current to stream which results in a frequent resistive heating. This has a propensity to keep large areas of the insulator surface dry, hence minimizing leakage current and reducing the arcing activity that leads to flashover [32].

Inappropriately, field tests presented that the glaze worsened in less than a year, predominantly nearby metal fittings where contact was made between the cement and the glaze. Experience has shown that, for a severely soiled glazed insulator, the instant of HV line energisation is when this insulator is most likely to flashover [33]. Therefore, alternative approaches were chased. One of the smartest methods of gaining the required resistance is to coat the porcelain with a semiconducting ceramic glaze having the preferred surface resistivity. Semiconducting glaze contains conductive oxides and a slight amount of antimony in addition to niobium-oxide, all in normal glaze base.

These additives were found to be effective in improving the performance of the glaze against corrosion. When tested it was confirmed that the voltage distribution is efficiently controlled and performance is significantly improved in contrast with that of similar insulators with normal glaze. Tests also showed that the leakage current of the insulator with semiconducting glaze stayed relatively low, and presented no current spikes [34, 35].In thorough investigation it was found that electrolytic corrosion was the main reason behind the worsening of the semiconducting glazes under polluted conditions, and also these semiconducting ceramic glazes were thermally unstable.These problems limited the acceptance of insulators with semiconducting ceramic glaze.

Though, it should be noted that a limited amount of achievement has been accomplished in reducing the number of flashovers compared with the performance of raw porcelain insulators [36]. Greases, like lubricants, are water-repellent, and since some oil-bath insulators had verified successful in service operation, it was valuable to investigate the behaviour of grease-coated insulators. Greases have been a prevalent method and are still being used by many utilities for insulator maintenance for curtailing contamination flashover. Grease mainly is a mixture of fumed silica and oil (fluid). The occurrence of grease on the surface of the insulator makes it hydrophobic and so the moisture tends to remain in discrete droplets. The contaminants are condensed by oil from the greasy surface, therefore retaining water repellence to the surface.

Moreover, the solid salts in the pollutant are overwhelmed by oil from the greasy surface and cannot easily be dissolved by water. For these two reasons, grease has been found to give a high flashover voltage to insulators in areas of hefty contamination [30]. Petroleum jellies and silicone greases are the most known types of greases.Petroleum jellies or petrolatum are acquired from a wide range of petroleum fractions, but are typically synthesized from hydrocarbon oils, slack and microcrystalline waxes. Under severe environmental and service circumstances petroleum jellies are stable due to their composition. With an increase in temperature jellies become soft, and melting is usually observed at the sites of current discharges. On cooling these coatings then resume their former properties. The temperature, at which this happens, the 'sliding temperature', is a vital characteristic of the material. This bounds their application to comparatively moderate climate conditions [32].

Initially, silicone greases were composed of inert filler, typically silica flour, fumed silica filler, or silicone fluid and a coupling agent. Since 1975, however, a new range of silicone greases have been available with the addition of alumina trihydrate; the concentration of which significantly changes the characteristics. Silicone greases maintain practically the same viscosity over a temperature range of -50° C to +200° C and do not melt so they can be used in all climates, but they decompose at temperatures above about 200°C. Apart from their high cost, their main disadvantage is that electrical sparking cause’s decomposition, leaving the silica filler and some solid carbon which then act as pollutants. The inorganic backbone of the silicone polymer is composed of silicone and oxygen atoms, exhibiting an increased resistance to UV degradation in comparison with petroleum greases having an organic backbone [36, 31]. Oil coatings neglect to give insurance to porcelain protectors from flashover under extreme contamination conditions, along these lines it should be supplanted routinely, which requires upkeep shutdowns of the electrical power system. This triggers the requirement for longer-enduring coatings with great electrical execution that oppose UV radiation, limit dry band arcing and require less support.

This has prompted the advancement and use of a defensive elastomeric covering for porcelain covers that can be utilized as a part of extreme pollution regions that require visit cleaning [37, 38, and 39]. RTV covering is a fluid polymer that vulcanizes when presented to dampness in air. Vulcanization is a substance procedure for changing over the elastic or different polymers into more solid materials through the expansion of corrective components. These added substances alter the polymer by framing crosslinks between singular polymer chains. Vulcanized materials are less sticky, and have predominant electrical and mechanical properties.

RTV silicone elastic insulator covering systems comprise of a polydimethylsiloxane (PDMS) polymer with an alumina trihydrate (ATH) or option filler. A few systems additionally contain a bond promoter, fortifying filler and pigment. These systems are scattered in a carrier medium, for example, naphtha or 1, 1, 1 trichloroethane, with the end goal that the RTV elastic might be connected to the insulator surface. Curing happens when the RTV covering is presented to climatic dampness. Basically, RTV covering materials are dissolvable based. After utilization of RTV on the surface of the insulator, the dissolvable dissipates, and the RTV vulcanizes noticeable all around and shapes a strong elastic covering. The sort of dissolvable, the curing chemistry and the relative stickiness of the air all decide the response rate by which this procedure is refined [40].

A RTV covering can be applied to a ceramic encasing by a procedure of plunging, painting or showering. Coatings scattered in 1,1,1 trichloroethane can be applied to invigorated covers with wellbeing safety measures, while those scattered in naphtha must not be applied to empowered insulators because of the inflammability of the carrier medium. The ATH filler is added to polymeric materials to bestow the covering imperviousness to tracking and disintegration (erosion) [41, 42]. There is impressive variety in the electrical and physical properties of the accessible details of RTV covering systems. Such variety is the aftereffect of the relative measures of ATH and fortifying fillers in the covering, the level of cross-linkage in the polymer, and the bond of the covering to the insulator surface. The properties of grip, water repellence and electrical tracking and additionally disintegration resistance are of foremost significance to ceramic insulator execution [43]. Silicone elastomers have long been known to keep up their hydrophobicity and water repellence attributes when presented to antagonistic climate conditions [44, 45, 46, and 42].

However, under delayed wetting conditions, the surface hydrophobicity can be lost incidentally and leakage current can be created. Restricted drying of the surface outcomes, which prompts the start of dry band arcing. The existence of ATH filler in the recipe of Silicone Elastic protectors assumes an imperative part in battling against material corruption through tracking and disintegration. The ATH filler disintegrates into anhydrous alumina and water if a temperature of over 220°C is accomplished [47]. Kim et al. [48] contemplated the impact of various filler levels on the covering execution and found that, in one hour tests coatings with expanded filler levels create higher leakage current sooner than coatings with bring down filler levels. In long term trial of 10 hours, in any case, coatings with expanded filler levels smother leakage current even after loss of surface hydrophobicity.

Pasand et al. [49] examined the impact of the filler sort on the resistance of the RTV SiR covering against tracking and disintegration utilizing the inclined plane test (IPT). The outcomes demonstrated that the ATH-filled coatings performed superior to anything that of the silica-filled coatings. The part of the extent of the ATH filler molecule and its impact on the electrical execution of the RTV-SiR has been inspected by Deng et al. [47] by testing polyester fibre glass bars covered with RTV covering in stimulated salt-mist. Meyer et al. [50] tried RTV covered examples with ATH and silica as fillers utilizing inclined plane tracking and disintegration tests. They found that the examples with 5.0 µm particle size and half filler by weight had higher warm conductivity and demonstrated less tracking and disintegration than different specimens with various molecule sizes and diverse filler rates.Venkatesulul et al. [51] considered the impact of nano-sized magnesium dihydroxide (MDH) and smaller scale measured ATH fillers as fire retardants in RTV silicone elastic. The examinations were additionally done utilizing an inclined plane tracking and disintegration test. At bring down filler groupings of 5% by weight, the MDH performed superior to the ATH as far as disintegrated mass. This is ascribed to the higher warm dependability of the nano-sized MDH filler. Thermal Gravimetric Analysis (TGA) results also demonstrated that MDH system was more thermally stable against disintegration. TGA is a strategy for warm examination in which changes in physical and chemical properties of materials are measured as a component of temperature.

TGA is ordinarily used to decide chosen qualities of materials that display either mass misfortune or increase because of disintegration and oxidation [51]. RTV coatings are scattered in carrier solvents, for example, Naphtha and 1, 1, 1, trichloroethane so as the RTV coatings can be effectively applied to ceramic encasings. Deng et al. [52] explored the impact of these two solvents on the execution of RTV covering. In their examinations, polyester rods were covered with RTV coatings having Naphtha and 1, 1, 1, trichloroethane as solvents and tried in a salt-mist chamber. In any case, it was accounted for that the kind of carrier solvent (1, 1, 1 trichloroethane and naphtha) does not impact the extent of LMW silicone liquid in the RTV-SiR; it likewise has no impact on dissemination of the LMW liquid from the mass material to the covering surface [53]. Measured contact angles on the surfaces of the virgin examples were observed to be indistinguishable for the two solvents.

Hoch et al. [54] utilized a silicone based hydrophobic covering for high voltage encasings. Explanation for this kind of covering was that the silicone based materials for covers showed better properties than different materials in like manner use. This has been appeared with in-benefit execution of silicon rubber long rods of both Room Temperature Vulcanized (RTV) and High Temperature Vulcanized silicon rubber (HTV). The essential purpose behind this unrivalled execution is the articulated hydrophobicity of the silicone material utilized. Liebermann [55] gave new powerful courses toward taking care of the issue of sullying of porcelain separators, first covering in light of Ormocer-sort varnish which is a material for solgel-sort coatings. It was covered onto the isolator skirts utilizing a spraying strategy. The second strategy in view of plasma-helped covering, hydrophobic plasma polymer shapes on the surface of the protector. The third approach in view of dip – covering and spray covering utilizing fluroalkylsilanes. A test report on account of voltshield encasing was done in 2003 which was later examined and given reasonable outcomes by Blackett [56].

Voltshield is a synthetically cross-connected polymeric resin with amazingly great non-stick properties utilized as a surface treatment intended to work with porcelain separators to upgrade their surface electrical execution under dirtied conditions. Amirhossein et al. [57] utilized superhydrophobic RTV silicone elastic separator covering, increment the dependability of electrical transmission systems and decreases the flashover and arcing over the whole protector because of self-cleaning impact. Water beads can get dust particles and expel tainting from surface of covers. On the premise of contact point more noteworthy than 145^0 demonstrated the superhydrophobicity of silicone covering on covers.

Ramirez et al. [58] demonstrated room temperature vulcanized (RTV) a powerful strategy against ruining, yet introduces a few weaknesses like low mechanical quality and poor maturing execution. Dave et al. [59] prepared hydrophobic hafnium oxide (HfO2) thin films to mitigate contamination problem. The hafnium oxide coatings were deposited on glass substrates by DC reactive magnetron sputtering from a pure hafnium target. The depositions of HfO2 films were carried out in O2 + Ar and O2 + He atmosphere. The structural, optical and hydrophobic properties were examined by varying O2/Inert gas ratio.

Dave et al. [60] developed hydrophobic coatings for outdoor insulators using sputtering technique. Hafnium oxide is characterized by high dielectric constant, large band gap (5.6 eV), high refractive index (2.1) and good mechanical, thermal and chemical properties. Hence it was observed that HfO2 was suitable as a protective coating for outdoor insulators used in the transmission line and transformers.

Dubey et al. [61] studied thermal stability and mechanical properties of Zr–W–N films. Zr–W–N films of various structure have been deposited on Si substrates by DC/RF reactive magnetron sputtering at various substrate temperatures Ts (100°–600 °C) and at constant N2 partial pressure (0.27 Pa). The study opens the scope of Zr–W–N nitrides as a potential coating material. It also reported that other compositions of Zr–W–N system may be more promising as coating material.

Dave et al. [62] prepared hafnium oxynitrides (HfOxNy) thin films as a protective coating for outdoor high voltage insulators. Hafnium oxynitride thin films had been investigated because of their remarkable properties in the domains of protective applications. HfOxNy thin films were deposited by DC reactive magnetron sputtering from a pure Hf target onto glass and quartz substrates at room temperature. Dave et al. [63] reported the structural, optical and electrical properties of nanostructured hydrophobic inorganic hafnium oxide coating for outdoor glass insulator using DC sputtering technique to combat contamination problem. The properties were studied as a function of DC power.

Dave et al. [64] investigated the effect of substrate temperature on structural, optical and hydrophobic properties of hafnium oxide coating deposited over glass insulators by DC magnetron sputtering. X-ray diffraction is applied to determine the crystalline phase and crystallite size of the film. Hafnium oxide being high-k dielectric has been successfully utilized in electronic and optical applications.

Castano et al. [65] coated the ceramic insulators with titanium dioxide films and evaluated properties as adherence, thickness and roughness of coatings and the contact angle on the coating surface was measured. Mazur et al. [66] presented an investigation that aims to develop and characterize hydrophobic aluminium nitride thin films, deposited on porcelain insulators surfaces, using direct current magnetron sputtering (DCMS). Different deposition times lead to different wettability characteristics, verified by sessile drop method.

4 General Recommendations

It is recommended that the emphasis shifted from traditional methods to Nanotechnology based coating has shown a promising impact on the dust removal from the high voltage insulators. There has been less research carried out over the dust removal from the insulator surface with this new technology.

5 Conclusion

This paper reviews the current state of research into the impact of dust deposition on the performance of high voltage insulators and also identifies challenges to further research in this area.The appraisal on the status of research has been discussed from 1988 to 2015 and also shown that the nanostructured coating methods can have better impact on the removal of dust from the insulator surface.

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