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Determining the contamination of various insulators for overhead transmission lines using N-FINDR algorithm

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Key words: Insulators; Contamination; N-FINDR; Leakage current; Electric potential.

Abstract: Environmental conditions can now cause power transmission cables to become insulators by lowering flashover voltage and increasing leakage current. Exposure to dust, moisture, rain, fog, and other unavoidable environmental factors can contaminate different types of insulators. As a result, contaminated insulators cause flashovers and grid failures, which have additional negative economic effects. The datasets in this study were run through the N-FINDR (N-dimensional finder) under a variety of environmental circumstances in order to determine the degree of contamination. The suggested method uses a variety of environmental circumstances to determine the level of insulator contamination. To assess the health of insulators, artificial pollution models were run on them by recording their leakage current data. Utilizing attributes from the gathered datasets, simulation is carried out. N-FINDR ascertains the level of insulator contamination in this manner. To quantify the level of contamination in insulators, factors such as electric potential, electric field strength, permittivity, ESDD (equivalent salt deposit density), accuracy, and leakage currents are measured and analyzed. By adding solvents like salt and water, analysis has been done to find out how different environmental conditions affect insulators, and the levels of contamination have been assessed. The suggested technique's efficacy is assessed simultaneously for a range of environmental variables.

1.Introduction

1.1 General Statement: Insulators are considered to be an essential component of the power system that can affect how well transmission lines and substations operate overall. An uninterruptible power source is necessary, for instance, for the electrical loads in steel mills and hospitals. Consequently, a significant loss of service could arise from any deterioration in the insulator’s performance. Depending on the material, there are two kinds of HV insulators: ceramic and nonceramic insulators and dependent on the overhead gearbox installation location lines shackle insulators, pin, suspension and strain insulators.

1.2 Literature Review

In literature, researchers have investigated the contamination of insulators using online monitoring methods and physical methods for knowing the pollution content in the insulators The hypothesis put forth by Holtzhausen et al. [1] was one of the first to be supported by science in explaining contaminated flashover. He utilised the schematic depicted to provide a very basic explanation of flashover. A segment of the arc produced by dryness band activity is connected to the polluted portion of the insulator, and a series resistance is used to illustrate this. Gerardo Montoya et al. [2] studied the behaviour of the level of pollution is highly dynamic when it is impacted by climatic variations. Ravi Gorur et al. [3] studied about insulators for cold urban areas and the problem of road salt and identified the pollution flashover of the insulator. Hamza et al. [4] in-depth research is done on the flashover properties of porcelain insulators subjected to simulated and real-world sandy conditions using and without electrified grids. Feilatet al.[5] developed the equivalent of salt deposition density (ESDD) found on insulator surfaces that are isolated from current power lines and/or field tests at stations is typically used to calculate the level of pollution. H. Saadati et al. [6] developed on the climatic conditions of insulators for the identifying the conditions of the insulators regarding its development in the service prone area and the contaminated area. Alexander Robert D. McAfee et al.[7] examined regarding the energies dispersive spectrum analysis (EDS), photo microscopy, x-ray diffraction (X-RD), and SEM (scanning electron microscopy) were used in the examination. Both the insulators' typical look and changes brought about by etching were observed. Hernanz et al. [8] identified the organisms developing on the insulators as algae and took pictures determining the extent of the pollution, or creating "zones of pollution.".

Ravi S. Goruret al. [9] used to determine the diameters, thicknesses, and conductivities of the elliptic contaminated layer variation are critical factors in the thermal insulation situation of high-voltage insulators, as demonstrated by the mathematical modelling of circular shaped like a polluted 230 kV dielectric strings using the finite element method, or FEM, and leakage current computation. Tsarabaris et al. [10] examined how contamination affects insulators will extend their lifespan and assist in resolving the increasingly serious issues related to insulator contamination. of insulators. Richards et al. [11] analysed the transient arcing behaviour was seen in this electrical activity, according to an analysis of loss current data. Moreover, the nature of this no steady state movement is tiny, sporadic, and broad band. Gerardo Montoya et al. [12] studied the contamination map to the creation of a leakage current measurement device that serves as an instrument for the in-service diagnosis of insulators mounted on gearbox lines. C. N. Richards et al. [13] studied the combined visible and infrared pictures to address the effect of moisture on non-contact techniques. Nevertheless, the two types mentioned above are both predicated on manually created features, the perception accuracy of which is heavily reliant on professional knowledge. Sugawara et. al. [14]and colleagues used radial basis function neural networks (RBFNNs) to detect contamination levels. Convolutional neural networks (CNNs) are one of the most extensively used image classification techniques nowadays. They have been applied to a variety of tasks, including segmentation [15-19] . CNN automatically and collaboratively solves the feature learning and classification issues together, in contrast to typical hand-crafted features [20]. This significantly increases the accuracy of picture classification.

1.3 Research Gap and Contributions. Several researchers have been focused on insulator contamination in great detail in the physical methods and some online monitoring methods however they have not focused on the contamination with regarding the electric potential and field strength and the leakage current. As the insulators are with high voltage very difficult to know the contamination level through the physical methods this may cause the hazardous to the lives more. To overcome the harm of life online monitoring methods have come forward however the level of contamination is not compared with the leakage currents in any kind of environmental conditions. There is need to develop an algorithm to determine the contamination of insulators with leakage current, electric field and potential of insulators. By using the image processing determine the industrial inspection, medical imaging, remote sensing etc can be determined.N-FINDR is an ongoing method for locating a hyperspectral data set’s endmember. The procedure makes the assumption that every simplex produced by the endmembers (purest pixels) has a volume greater than any other simplex defined by any other set of pixels.

1.4 Research Objectives:

The main reason for taking this algorithm is to determine the contaminated levels of insulators without the physical methods and conventional online monitoring methods, testing, calculating etc to overcome the time factor and damage the proposed algorithm N-FINDR is used to determine the contamination level of insulators.

Among the following main contributions of this work includes the following,

- Determining the contamination of various insulators containing porcelain, glass and ceramic insulators.
- Calculation of the leakage current for various insulators to find the contamination level.
- Determination of electric field and potential for various insulators and in turn ESDD (equivalent salt deposit density) for increasing level of contamination.
- Comparison of the pollution contamination using permittivity with the proposed method and online monitoring techniques which is available in literature is done.

1.5 Advantages of N-FINDR algorithm:

- **Remote sensing**: Algorithm is the method of identifying pure elements from satellite or aerial hyperspectral pictures, such as minerals, vegetation, or urban materials.
- **Environmental Monitoring**: Analysing hyperspectral data from the environment to identify particular pollutants or toxins.
- **Agriculture**: Identifying various vegetation kinds or spotting pollutants on crops in order to monitor crop health.
- **Imaging**: N-FINDR facilitates the identification of unique spectral signatures of tissues, and hyperspectral imaging can be utilised in medical diagnostics to distinguish between different tissue types.

In this paper,N-FINDR algorithm of an image processing is our solution to the problems mentioned before. Physical, chemical and mechanical properties of insulators are being considered to determining the contamination of the insulators. A data sets consisting of 7000 images of insulators are taken. The representation of data is sub divided into 3 classes train class with 5896 test class with 740 and Val class with 364.N-findr algorithm works with by choosing the ‘N’ value depending the number of insulators taken as datasets and then simulation is done. In order to assure correctness, validate and assess the data using the

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proper metrics and professional analysis (step by step method). Calculation of the leakage current for various insulators to find the contamination level. Electric field and potential for various insulators and in turn ESDD (equivalent salt deposit density) for increasing level of contamination will be determined. Comparison will be done on the pollution contamination using permittivity with the proposed method and online monitoring technique.

1.6. Article Structure

The article is organised as follows: section 2 explains the mathematical modelling of contamination using N FINDR. Section 3 details the analyses the Contamination of insulators using N FINDR and section 4 deals with the challenges and future enhancement. Section 5 offers the conclusions and potential future enhancements.

2.MATHEMATICAL MODELLING

Several important factors must be taken into consideration when calculating the degree of contamination of insulators, especially when dealing with high-voltage electrical systems. These features aid in determining the level of contamination or pollution on insulators' surfaces, which may have an impact on their functionality and result in problems like flashovers. The main variables at play are as follows: ESSD and permittivity.The ESDD value is computed using the subsequent mathematical expressions.

A. Water Conductivity

The water conductivity (σ_t), as determined by a measuring the conductivity and probing the conductivity at 20 °C (σ_{20}),

$$\sigma_{20} = \sigma_t\ [1 - b\ (\ -20^{o})\ ]. \qquad (1)$$

where:

σ_{20} =the solution's rectified conductivity (µS/cm) at 20 °C;

$\sigma_t = solutionconductivityatthetemperaturet$(µS/cm);

b== temperature-dependent factor;

t = solution's temperature (°C).

The factor, b, at a given temperature, t, is given as:

$$b = -3.2\times10^{-8}t^3 + 1.032\times10^{-5}t^2 - 8.272\times10^{-4}t + 3.544\times10^{-2}. \qquad (2)$$

The salinity, S = $(5.7\sigma_{20} \times 10^{-4}\ )$ 1.03. (3)

$$ESSD = \frac{SxV}{A}. \qquad (4)$$

V= volume of the distilled water (cm^3)

A= surface area of insulator

B. Leakage Current Due to Contamination

On the surfaced of a polluted insulator, the leakage current I_l can be written as follows

$$I_l = \frac{V}{R_s}. \qquad (5)$$

I_l = leakage current (Ampere)

V=applied voltage across the insulator

R_s =surface resistance of contaminated layer

$$R_s = \frac{\rho_s * L}{A}. \qquad (6)$$

ρ_s=surface resistivity

L= length of leakage path along the insulator

A= cross sectional area

C. Electric potential

The resistances of the contaminated layered and the distribution of leakage current cause variations in the electric potential along the surface of a contaminated insulator. If the potential at a point x along the insulator is represented by V(x) = $V(x)$ then the potential decrease along the surface may be written as follows:

$$E = -\frac{dV}{dx}. \qquad (8)$$

D. Electric Field strength

The potentially gradient and the electric field strength E along the contaminated insulator surface are connected:

$$E = I_l * \frac{\rho_s}{A}. \qquad (9)$$

E =electric field strength along surface

$\frac{dV}{dx}$ = potential gradient along surface

ρ_s = surface resistivity

I_l = leakagecurrent

3.Proposed Methodology

The N-FINDR technique is a member of the originalquality of the shape-based class of techniques for spectra’s that rely on the belief that each endmember in the input data has a minimum of one pure pixel.The property that continuously mixed vectors belong to a simplex set is used by geometrical techniques. Every vertex of the data simplex is assumed to have at least one spectral vector by pure pixel-based methods. These algorithms search for the group of the clear and original quality in the data, could not improve true for many datasets.

The N-FINDR technique inflates a simpler in representation within the data to determine the endmembers, and then determines the group of originalquality would provide the largest practical simplex volume. The endmembers are presumed to reside in the vertex of the greatest simplex through the spectral dimensions, because the volume defined by the simplex created by the purest pixels is greater than any other volume defined by another combination of (non-pure) pixels. The suggested technique is depending upon a master-slave techniques that is designed to run in a cluster of computers. The method's design happenswith account the characteristics of shape of the features. The primary moto is to use N-FINDR to process every subsetwithout dependent in a node by performing a preliminary processing process at the node which contains of a different data separation. Only those datapoints that are deemed are returned to the node once the endmembers linked with each subset have been identified. The master node then performs N-FINDR once more, however only over the candidate endmembers.

Figure 1 shows the algorithm for determining the contamination of insulators using the N-FINDR. The above algorithm describes the images is taken as input then it preprocesses the data with the help of dimensions and then initialize the data and finds the end members i.e. contaminants. Figure 2 shows the dataset for p = 3 end members is shown geometrically in (a), is randomly partitioned in (b), is found to contain simplexes at each processing node in (c), and is processed to include promising end members at the master node in (d).

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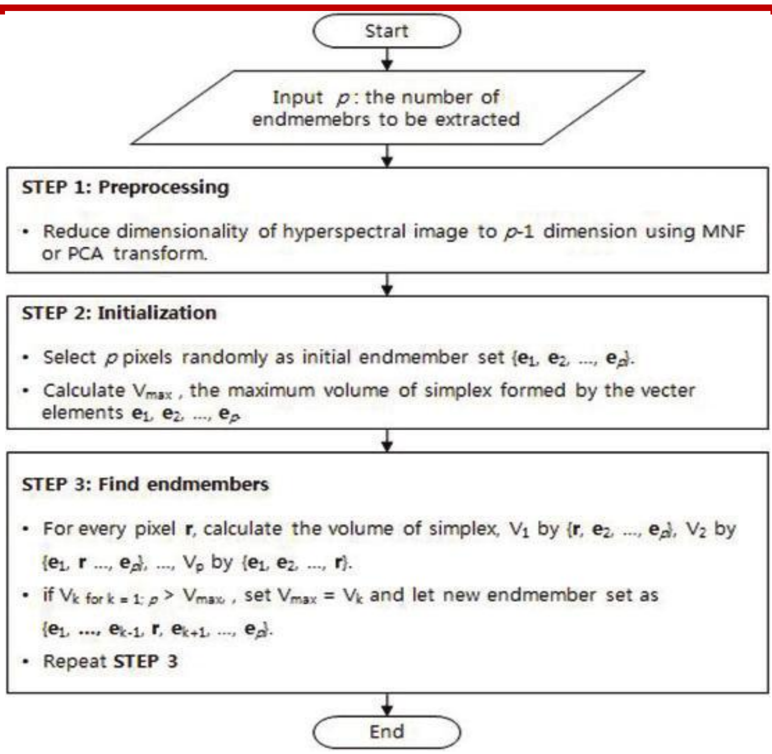

Fig.1 Algorithm for N-FINDR

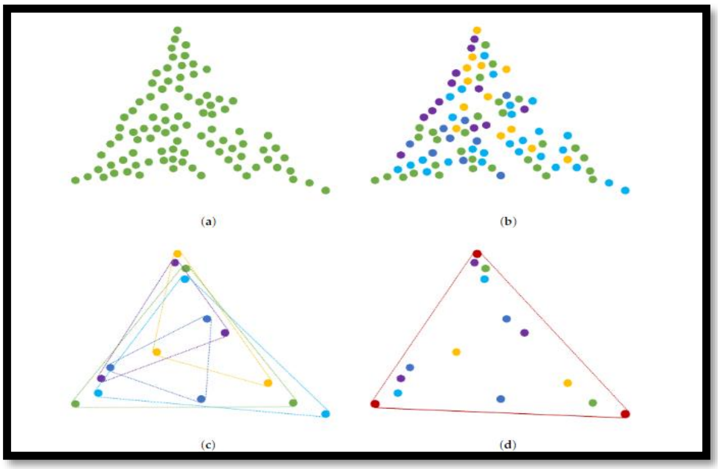

Fig.2 Layout of Algorithm

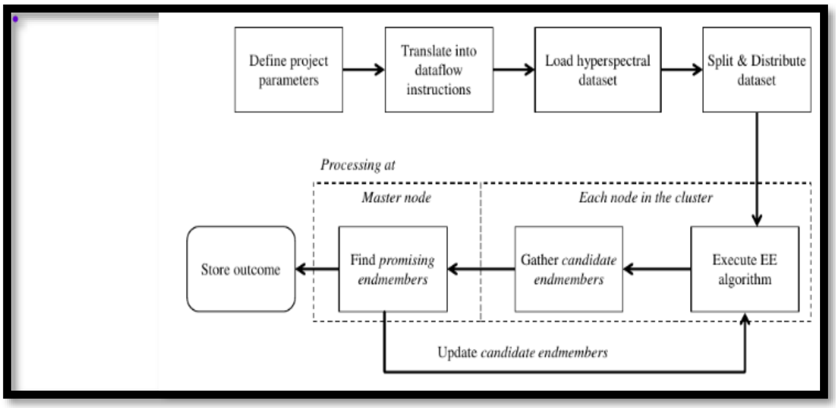

Fig.3Flow chartfor N-FINDR structure

Fig 3 describes the candidate endmembers, every hyper spectrallysubsite is handling independently at each processing node in accordance with a hierarchical system Next, in order to determine what we referred to as potential endmembers, a node collects these end user and processes then utilise the similar end user extracted algorithm. The end useris re-distributing and everyprocessed unit verifies these enduserson local subsets in order to assure their validity. The final results are then stored into a cloud repository. The procedure is multiped until the simplex reaches its highest volume, at which point its vertices are regarded as the end of the endusers for the entire hyperspectral dataset being analysed.

Step wise procedure to find pollution contamination when N-FINDR is applied to insulators:

- Using the feature fingerprints of the various components, take hyperspectral pictures of the insulator.
- Preprocess the data by normalising it, eliminating noise, and maybe dimensionality reduction.
- Choose the first endmembers at random to symbolise any possible impurities or materials on the insulator.

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- Determine the first endmembers' spectral volume using a simplex-based method
- To maximise the dispersion in spectral space, iteratively swap off endmember pixels for pixels that raise the spectral volume.
- Until no more volume can be added, keep doing this to make sure the endmembers with the highest spectral purity are identified.
- Lastly, locate endmembers and map them to the various impurities on the insulator.

4.Results and Discussion

Dataset consists of high-resolution photos of insulator having with malfunctioning parts, can be found. As may be seen, the insulators in the database having various insulators in a range of having the different environmental group of the insulators, registered in various positions with different images backgrounds. There are totally 7000 images of glass insulators these are sub divided into 3 classes train class has images with 5896 test class with 740 and Val class with 364. The components are identified according to the width, height, and vertical and horizontal positions of the bounding boxes.

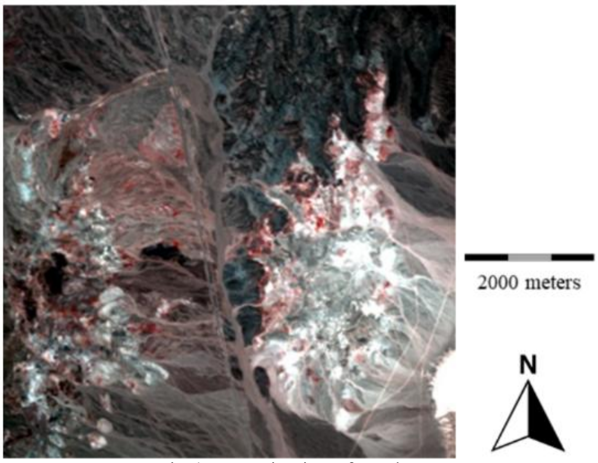

Fig.4Contamination of Insulators

Fig.4 shows the contamination of the insulators. By this algorithm can identify the contamination present on the insulators due to environmental conditions like fog, mist, dust particles etc.

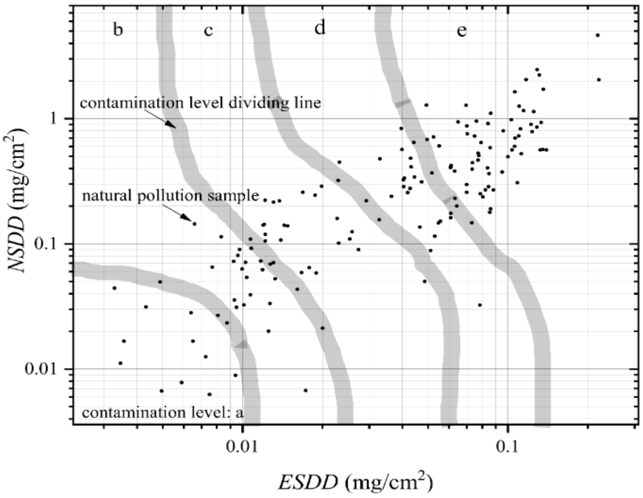

Fig .5 Variation of NSDD over ESDD

The fig.5 describes insulation, the modification of creepage, and the identification of pollution contamination level all heavily rely on the NSDD/ESDD ratio. Furthermore, the ratio's analysis aids in figuring out the true level of pollution at the location.

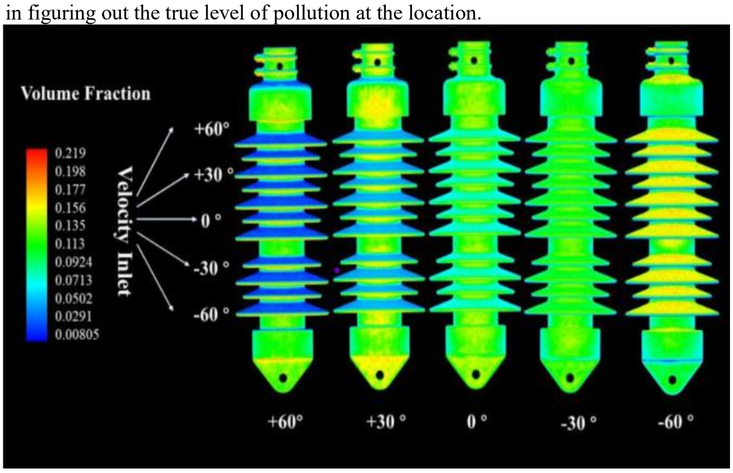

Fig.6 Analysis of the state of pollution at various wind angles

The above Fig .6 determines the state of pollution of various insulators with the spectral analysis using the N-FINDR algorithm.The following are the colour indications: The hue blue denotes an extremely low degree of contamination in the insulator. The colour sky blue denotes a pollution level greater than 1. The colour green denotes a contamination level of two. The hue yellow denotes a contamination level of three, while the colour orange denotes a higher level of contamination.

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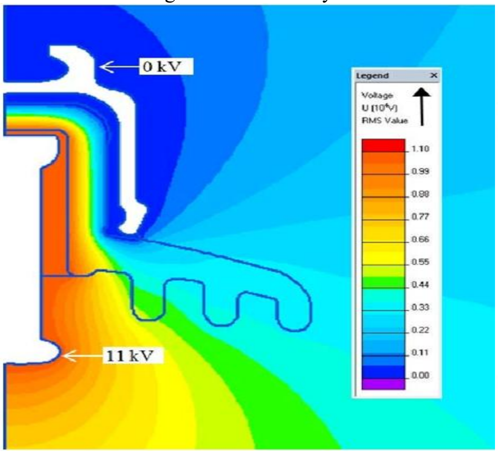
Table 1. Permittivity of various materials

No	Case	Permittivity
1	Contamination	78
2	Salt	12.5
3	water	80

The above Table 1. shows the permittivity of insulator in various cases like contamination, salt and water. From the above infer that contaminated and water case show nearly same permittivity due to presence of ions on the insulators are covered and the permittivity of insulator increases. In the moisture type of environment this algorithm works very better. As it shows the contamination with very less it gives the accurate level of contamination of insulators is known.



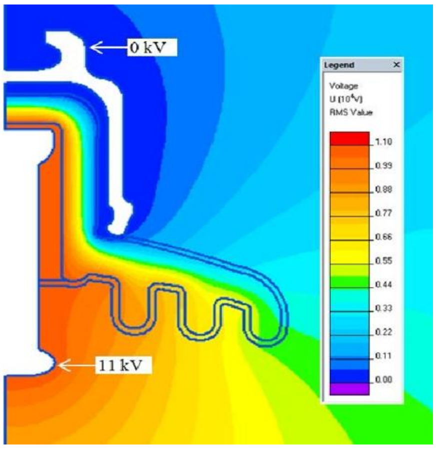


Fig.7 Voltage distribution of clean insulatorsFig .8 Voltage distribution of contaminated

Figure 7 and 8 shows the voltage distribution of clean and contaminated insulators. The figure describes the contaminated level of insulators is more rms value than the clean insulators.The homogeneous distribution of voltage on clean insulators guarantees consistent electric field strength and dependable operation. Pollutants and moisture cause an unequal voltage distribution in contaminated insulators, which concentrates the electric field and raises the possibility of flashover. Insulation strength declines with increased contamination, which can result in localised electrical stress and eventual breakage.Previously, conventional online monitoring is used to determine the level of the contamination but now our methodology is using the N-FINDR algorithm. Comparison of conventional online monitoring and N-FINDR algorithm with parameters of contamination such as ESDD and leakage current.

Table 2. Comparison of proposed method with method available in Literature

Algorithm	ESDD (mg/cm^3)	Leakage current (mA)
Online monitoring	0.25	0.1
N-FINDR	0.10	0.01

Figure 9 shows the comparison of algorithm. From the above table observe that N-FINDR has less ESDD and leakage current. The ESDD displays the degree of insulator contamination. Only 0.25 is the ESDD value that can be found using the prior approach. However, our suggested technique can assess pollution up to 0.01 as well, indicating that it is more accurate than existing algorithms. From the Figures 10 (a) and (b) infer that leakage current of N-FINDR algorithm is less. As less the leakage current the contamination of the insulator detected is very less i.e. show the small contamination also using the N-FINDR algorithm. Similarly, ESDD having less determine the contamination is less in insulators. Hence by comparing the algorithms, infer that N-FINDR provides the best result of contamination even with the minute pollutant also proposed algorithm is calculated and determined.

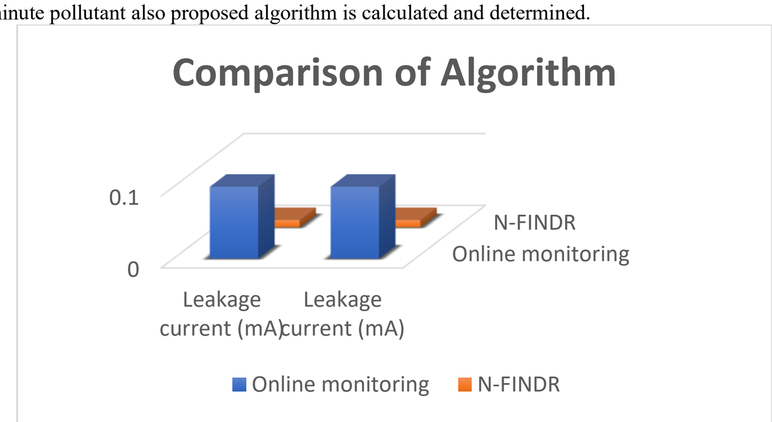
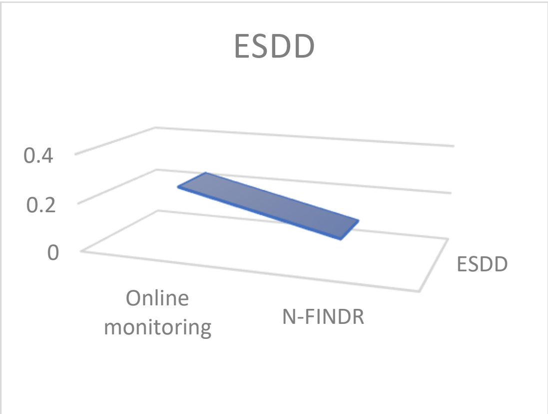


Fig.9 Comparison of Algorithms



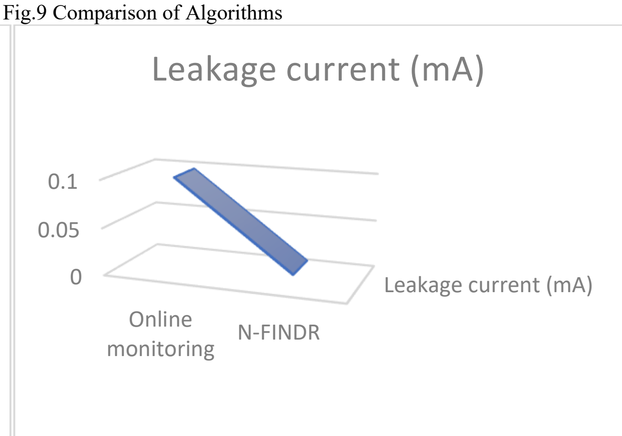


Fig .10 a Comparison of ESDD Fig.10 bcomparison of leakage current

5.Conclusions

After reviewing the contamination level of insulators in a variety of settings and situations, the following findings are drawn.

- In the study, electrical, physical, and chemical parameters can be employed to define the contamination of various insulators. varying qualities for varied detection techniques, but a non-contact monitoring approach is preferred to make field deployment easier.
- Contamination level of various insulators is determined by analysing the leakage currents, NSDD and ESDD, the proposed algorithm N-FINDR finds good for small contamination also.
- Electric field strength and permittivity is analysed. The voltage distribution of insulators is uneven as the contaminated insulators have more voltage so stress get increased.
- Decreasing contamination increases the lifespan of insulator more.
- N-FINDR algorithm measures the contamination with less value also. Minute contaminated also this algorithm is determined. With this the insulators are updated every time then lifespan also increases.
- Distinct material optimisation techniques should be used in various application settings. Thus, future research on anti-contamination enhancement techniques for various contexts is necessary.

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