



REVIEW ON DETECTING THE CORONA DISCHARGE OF TRANSMISSION LINE USING RF ANTENNA

Sneha Milind Punde¹

¹T.E. Computer Engineering, RMD School of Engineering, Warje, Pune-58, Maharashtra, India

Abstract – Disclosure of corona discharge of the transmission line can reflect its health status and provide warning information for maintenance. Some existing detection methods are flawed and cannot be used widely. This survey is based on a study of method by measuring the electromagnetic wave caused by corona discharge with RF antenna. Then a circularly polarized log-periodic antenna was designed by making two pairs of log-periodic antennas 90° orthogonal. Finally, this antenna was simulated and assembled to detect electromagnetic signals, the outcome displays that the time domain signal of corona discharge is a high frequency oscillation wave and its fast Fourier transform main distributes between 200 and 350 MHz.

Keywords – Circularly polarized log-periodic antenna, Corona Discharge, Electromagnetic signal detection, Fourier transform, High frequency oscillation wave, RF antenna, Time domain signal, Transmission line.

I. INTRODUCTION

Corona discharge of transmission lines and equipment is the focus of the State Grid, which will cause electromagnetic interference, energy loss, and also accelerate the ageing of insulators. Catching the discharge anomaly meticulously can help the power sector to asset hidden problems early and avert serious economic losses. In addition to daily visual inspection, the main current means of monitoring discharge are infrared thermal imaging and UV imaging [1–5], the ultrasonic corona detection is used in transformers sometimes [6]. Visual inspection devour labor, also is perilous and capricious. The infrared thermal imaging can detect successfully only when the discharge develops seriously so as to increase the local temperature. UV image can position the discharge point exactly, but its price is too high, so considering economic costs, it cannot be used widely. The advantages of ultrasonic detection method are almost not affected by the local electromagnetic interference and could locate the discharge, but its sensitivity is poor. Pulsed electromagnetic radiation field will generate during the corona discharge [7–19], for the purpose of detecting failures of transmission lines conveniently and early, method in this paper was presented through calibrating this pulse electromagnetic wave with RF antenna. Based on the log-periodic antenna, which has the aspects of ample bandwidth, high gain and good frequency characteristic, but linear polarization, two pairs of log-periodic antennas are combined orthogonal to each other, aimed at constructing a circularly polarized antenna.

II. LITERATURE SURVEY

In 1976, Sebo et al, reviewed experiments performed in two high voltage laboratories. Three cret and seven conductors (solid and ashore, single and bundle arrangements) were used for dry and wet experiments. About 1300 test points were obtained, encompassing a wide range of voltage gradient and corona loss values. Qualitative and quantitative analyses were conducted. Measuring equipment and experience are discussed. Inspections show that the mostly average ratio of corona loss to ozone production was about 0.52 kWh/g of 0 3 (235 kWh/lb of 0 3), based on all of the experiments. Long-term field tests were conducted and an experimental measurement program extending several months before and after energization of a 765-kV line was carried out. All of the lab and field survey proved that the ozone levels and production rates within the actual operating voltage gradient and corona loss region were very low, and the ground level ozone concentrations due to EHV transmission line corona were indistinguishable from ambient ozone concentrations [4].

Bian et al in 2012 inspected on effect of surface roughness on corona discharge for a 30-year operating conductor in the first 500-kV transmission line in China. Many substances were detected to comply to the conductor surface. Corrosion and deposits had rendered the operated conductor surfaces much rougher than those of the new one. The conclusion show that surface roughness has a compelling impact on corona discharge, and the corona inception voltage of the operated conductor would be decreased while the audible and radio noise would be increased [2].

In 2008, Cheng et al, investigated The corona pattern from porcelain insulator strings on high voltage (HV) transmission lines for The corona pattern from porcelain insulator strings on high voltage (HV) transmission lines. Corona patterns from HV conductive line, metal accessory, and discharge patterns from bad connection, power stations, have also been studied for background pulse noise elimination. A pattern recognition approach for auditing inadequate porcelain insulators is proposed, which consists of certain criteria. It was observed that the harmonics and carriers from the transmission lines controls the recognition vigorously, which can be eradicated by choosing a high frequency band of sensors (2 MHz-20 MHz). Based on the above analysis, a device was designed and used on the field measurements in Lanzhou and Zhengzhou power adequacy in China. The field consequences displayed a stable abutment for this method. On the measurement of 76 towers, the measuring accuracy of inspecting faulty insulators was about 87.5% [3].

In 2016, Yi et al, presented their work in “Influence of surface contamination of conductor on positive corona-generated audible noise spectrum characteristics of HVDC system”. The results revealed that the spectral components of the audible noise of clean conductor were obviously different with the increase of the applied voltage. The spectral components (>1kHz) of the polluted conductors were much higher than those of the clean conductors. The contamination adhering to the surface of conductors affected spectral components (>1kHz) much more obviously than low spectral components, and the results were analyzed in this paper. The conclusion laid a foundation for researching the influence of the surface conditions on the corona-generated audible noise [5].

The paper “Measurement method of ionic mobilities in direct current corona discharge in air” in 2016 presented a measurement method of ionic mobilities in air. The rational solution of ion mobility was derived from the equations of the ionized field and the ion current density. A circular parallel plate apparatus was applied to measure the ionic mobilities [8].

Bo Zhang, et al in 2013 presented paper “Analysis of ion flow field of UHV/EHV AC transmission lines”. In their work, the calculation method of the ion flow field of AC transmission lines based on the charge simulation method was improved. As the previous works, the problem is solved in time domain with representing the space charges as discrete line charges. In every distinct time step, the processes of charge emission, space charge displacement, and space charge recombination are imitated. As advancements, the control of the conductor surface field consistency on corona discharge is taken into account, so that the ion flow field of multi-phase or bundle conductors can be imitated in this work. The corona losses of a 3-phase 8-conductor bundle HVAC transmission line is computed. Acceptable agreement is obtained with the experimental results. The ground level total electric field of distinct line configurations is computed. The control of line structures such as sub conductor radius, bundle spacing, number of sub conductors, wire spacing, and phase height on ground level total electric field are analyzed based on the calculation [9].

The paper “New formulas for predicting audible noise from overhead HVAC lines using evolutionary computations” presented by Yang et al in 2000 revealed results of applying evolutionary computation techniques using AN data from lines all over the world to design new highly definite formulas for anticipating the A-weighted AN during heavy rain and stable rain from overhead AC lines. Calculated ANs using these new formulas and existing formulas are compared with measured data [14].

Lee et al in 1983 presented the paper “Non-Linear Corona Models in an Electromagnetic Transients Program (EMTP)”. This paper described the implementation of a simple and accurate numerical model representing the non-linear corona phenomenon in a general-purpose electromagnetic transients’ program (EMTP) for lightning over voltage studies. Single phase representation of multi-phase transmission line for short distance below 2 km are used. Field test measurements on a 600 kV line, are duplicated with the transient’s program and the developed corona model. Corona loss constants are also obtained empirically under different conductor configuration and wave polarities [16].

III. LIVE SURVEY

In 2020, Xiaoming Xiao et al presented their work in “Design and Optimization of Detection Antenna for Corona Discharge in High-voltage Transmission Lines”. In this paper the finite element method is used to study the 5th order Hilbert fractal antenna. The research focused on the different feeding positions of the antenna. By studying the different feeding positions of the antenna, they determined a miniaturized antenna which can be used for corona discharge detection of high-voltage transmission lines [22].

Jian wang et al presented a paper “An outdoor remote detection method for corona discharge based on convolution window bandpass filtering of its electromagnetic radiation mainly in microwave-band” in 2019. In order to increase the sensitivity and detection distance of corona discharges which cover the frequency band up to 1000 MHz or above, this paper proposes a novel corona detection method based on bandpass digital filtering. Based on a deep spectral investigation on background signals and corona discharge signals, it is discovered that there exists a narrow characteristic band from 230 to 270 MHz which can be developed to improve corona detection with high signal-noise-ratio using helical antenna. Accordingly, a novel convolution window based digital filter design was proposed. It can not only accurately realize the mentioned bandpass filter's cut-off frequencies but also greatly suppress the electromagnetic interference. Moreover, to enhance the proposed method's design efficiency, the filter parameter configuration for corona detection and a closed-form formula of filter coefficients were also derived. Field experiments verified the proposed method's feasibility and high sensitivity, and showed that the maximum measurable distance of this apparatus can reach 150 m [23].

In 2020, Yong Wu et al studied current characteristics of corona discharge in high voltage transmission and collected results in “Analysis of current characteristics of corona discharge in high voltage transmission”. In order to study the current characteristics of corona discharge in high voltage transmission, the time-domain characteristics and volt ampere characteristics of corona discharge under different high voltage are tested and analyzed. The actual test results show that: in the whole process of corona discharge, with the increase of inter electrode voltage, the frequency of pulse current increases, and the duration of current remains unchanged; negative corona discharge is more likely to occur, and with the increase of voltage, the average current growth rate is higher than positive corona discharge. Under the

same interelectrode voltage, the negative corona current is stronger than the positive one. The nonlinearity of equivalent resistance between positive corona discharge electrodes is stronger than that of negative corona discharge [24].

In June 2019, Chaoqun Li et al researched on Electromagnetic Radiation Model of Corona Discharge with UHV AC Transmission Line. The corona discharge characteristics are analyzed and compared with the measured results of 1000kV UHV ac transmission line. The results show that the electromagnetic field strength increases first and then decreases with time, and at the same time, the electromagnetic field strength decreases exponentially with distance. The simulated and predicted corona discharge radiation characteristics have the same variation law as the measured data, which verifies the correctness of the model [25].

In 2020, Kirill Tyurikov et al, presented “Corona discharge plasma application for the deposition of nanocomposite coatings”. According to them, Corona discharge in helium plasma was used to perform deposition process of nanocomposite coating in “molybdenum disulfide – silicon dioxide” system. 2 kV amplitude and 28 kHz frequency discharge was applied to tetraethoxysilane vapors for them to decompose and form silicon dioxide layers. Negative 2 kV bias was used to route negatively charged in plasma nanoparticles to the deposition region. Plasma absorbed power effect in the range of 50–90 W was studied [26].

Jing Wang in 2020, reviewed on the recent development of corona wind and its application in heat transfer enhancement. In this review, the formation process of corona wind and the mechanism of local heat dissipation enhancement are deeply investigated from the perspectives of physics, electricity, and thermodynamics. Related literature published in the past decade that has focused on the application of small-scale corona wind generators (CWGs) in local heat transfer enhancement is classified and discussed. Some important research conclusions are highlighted and used to guide the optimal design of a small-scale corona wind cooling system. The ongoing challenges of the power supply, adverse effects of byproducts, humidity, and electrode deterioration are discussed, and corresponding solutions are put forward. The use of corona wind cooling technology will present opportunities based on the research that has been conducted and its future development tendency [27].

IV. DISCUSSION

In high frequency structure simulators (HFSS)[20], two symmetrical metal tubes are established to be the ‘bus’ of the log periodic antenna, which is used for connecting the dipoles. Also, then nine dipoles are placed crossover in line to achieve the purpose of cross-connection of buses.

In this model, the feeding is finished by coaxial cable, then one log-periodic antenna is built up. After that the model is replicated and then rotated 90°, and one pair of dipoles are added, finally another log-periodic antenna is formed. In this way, two sets of log-periodic antennas orthogonal to each other are finished. The two pairs of log-periodic antennas are fed by coaxial cables in parallel, and adjust the distance between them to be fully circularly polarized, and then run the model, we can get its 3D lobe diagram. It shows that the circularly polarized log-periodic antenna has a good directivity and has a high gain in the axial direction along Z-axis, which meets the requirements of this designed antenna [21]. The simulation results continue to be analysed, the antenna gain can be up to 12 dB, and the antenna has basically no side lobes. The designed antenna has good radiation characteristics obviously [21].

S11 of circularly polarized log-periodic antenna can reach -12 dB about 240 MHz, where the antenna can accept better signals, and the detection band contains the originally required center frequency 250 MHz [21].

To detect electromagnetic signals of corona discharge caused by composite insulator with two piece, a discharge platform was built in the lab. The electromagnetic signals were accepted by designed antenna above, after band-pass filtering and amplifying, the signals were sampled by a Tektronix MOD4034B-3 high-speed oscilloscope. When there is no discharge, the noise signal is observed. The time-domain signal and its spectrum has some bulges, such as 90 MHz to 100 and 900 MHz, scattered in the spectrum. The bulges are considered to be the interference noise of the radio and the mobile station, the noise signal exists all the time[21].

Then the voltage was increased to 38 kV, and noticeable sound of discharge could be heard. The detected electromagnetic pulse signal and its spectral distribution of fast Fourier transform-converted. The signal is spasmodic. It shows the time-domain signal is a high-frequency oscillation wave, and the main spectrum is between 200 and 350 MHz [21].

Therefore, the designed circularly polarized log-periodic antenna in the paper can detect the discharge signal of the composite insulator under high voltage. The amplitude of the detected signal is weaker as the voltage decreased. It is considered that the amplitude of the corona discharge signal detected by the antenna is related to the applied voltage, which needs further verification [21].

V. CONCLUSION

A circularly polarized log-periodic antenna was designed by making two pairs of log-periodic antennas orthogonal, and through simulation and experiments its validity was verified. The sampled electromagnetic signals of corona discharge showed the main spectrum is between 200 and 350 MHz. Further tests on the transmission line and design of portable detection system will be carried out in the future.

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Links

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