



## Paper Information

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Authors	Umesh Soni, Shailesh Patel
Affiliations (optional)	NA.
Country	India
Email address	umesh.soni@erda.org

## Summary

Operating and maintaining HV switchyard is a challenging task. Failure by a slightest margin can lead to the collapse of the system, and such collapse can lead to severe consequences in power system. So it is essential to maintain switchyard in an operating condition for a longer period to deliver an uninterrupted power supply. Currently various online technique available for monitoring the insulation health of switchyard HV equipment. Apart from this there are various conventional diagnostic tools available for assessing the condition of power transformers & HV switchyard equipment.

This paper depicts the online monitoring of the various switchyard equipment with the help of noiseless acoustic camera which can give preliminary idea about the discharge activity in switchyard equipment. The new emerging acoustic camera (NL camera) method show good performance in monitoring insulator conditions, their high sensitivity to environmental weather, such as dust and rain, influences the accuracy of the results. Partial discharges emit broadband sounds that can be both audible and inaudible. The camera combines both sonic and ultrasonic frequencies to detect partial discharges as accurately as possible, finding partial discharges that are often completely inaudible to the human ear. The Camera can find partial discharges that are missed by UV and IR cameras that you do not have direct line-of-sight. This instrument is a measurement instrument comprising many microphones for locating sound sources & optical sensor to co-relate the image Also this paper gives a review of the various online techniques utilised for monitoring of switchyard equipment. Interpretation of the data obtained from testing was carried out and based on that the type of discharges were identified. The test details provided in the paper would enlighten the operations and maintenance personnel regarding the techniques used while testing of the switchyard equipment. Also various case studies discussed were discharges were obtained in the various equipment. One case study depicts the co-relation of online noiseless acoustic techniques with the electrical method of discharge detection.

In this paper one laboratory experiment is also depicted to validate the effectiveness of noiseless acoustic camera. The electrical Partial discharges (PD) were measured for transformer using direct

detection method using three PD channel and observed the correlation while detecting through noiseless acoustic camera.

## Keywords

Partial Discharges, Noiseless acoustic camera, Switchyard

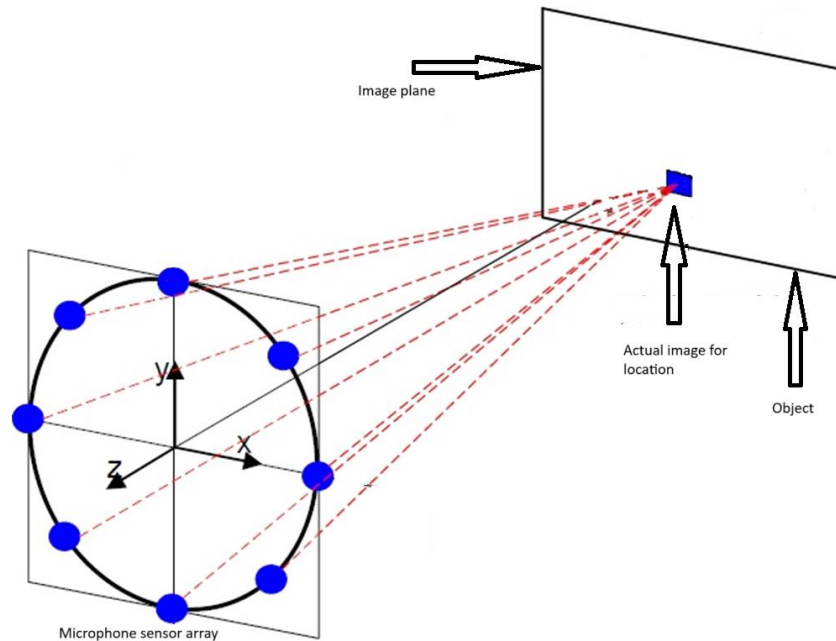
## 1 Introduction

The evaluation of the performance of insulations in HV equipment continues to be a significant topic in the high voltage community. The use of partial discharge measurement by various techniques has been popular and offers many advantages. In recent times, acoustic and RFI based diagnostic methods have been used to evaluate the health of Insulations [8]. However disadvantages are associated with the RFI technique is that it may detect the discharge activity however pinpointing the same may not possible as various source of discharges are there in substation & distinguish the discharge location is difficult.

The new emerging Noiseless acoustic camera (NL camera) method show good performance in monitoring insulation conditions, their high sensitivity to environmental weather, such as dust and rain, influences the accuracy of the results. Partial discharges emit broadband sounds that can be both audible and inaudible. The camera combines both sonic and ultrasonic frequencies to detect partial discharges as accurately as possible, finding partial discharges that are often completely inaudible to the human ear. The NL Camera can find partial discharges that are missed by UV, IR cameras and RFI plotter that you do not have direct line-of-sight.

In 1970 multiple microphones forming the array first utilized to localize the sound source. With time & development of the data acquisition system significant improvements has been made in this technique. From the year 1999 modern cameras comes in to lime light. Noiseless acoustic camera is a measurement instrument comprising many microphones for locating sound sources & optical sensor to co-relate the image (Figure 1). The beam forming technique will result in highly directive response in these cameras. Noise comes from different areas can be detected with this technique & amplification of noise coming from area can be amplified by suppressing the noise from unwanted part with this

technique. This noise maps are computed in real time & then they are over laid on the video image. This enable to get the image with noise demarcation.



*Figure 1 - Working principle of noise less acoustic camera*

This acoustic cameras are best suited for switchyard discharge monitoring as sound source are omnidirectional far from the array of microphone which is accurately detected by the camera. One of the challenge with the acoustic camera is resolving the low frequency acoustic signals which has the longer wavelength, which do not allow the strong directivity for the accurate measurement. However the PD signal in air has the velocity in the range of 20 kHz to 1 MHz which are pin pointed <sup>[6]</sup>. As the wave length of signal are much smaller than the array size, accuracy of the measurement is high in this camera for PD acoustic signals. One need to take care while using this technique indoor as chances of ghost image due to reflection from the floor surface & wall surface may interfere in the measurement. Near field acoustic holography can be utilized for the noise source which are very near to the microphone array.

The advantages of this method are:

- The NL camera is useful to monitor the condition of overhead line insulators, CT,CVT & bushings
- Discharge detection from NL Camera is simple, low cost, and accurate.
- Applicable for any insulation type and any voltage level. Monitoring insulation conditions on the transmission line & power equipment without disturbing the operation of the

system.

- Noise less acoustic camera provides a visual identification and quantification of sound, similar to a thermal imaging camera.
- Power system reliability can be achieved and also gives information about present condition of HV insulations & early indication of failure.

NL Camera (Figure 2) detects and localizes a partial discharge based on the sound it emits, recognizing and distinguishing it from other sounds. The on-device analytics then shows the PRPD (phase-resolved partial discharge) pattern that depicts the partial discharge's behavior and helps to classify the discharge type.



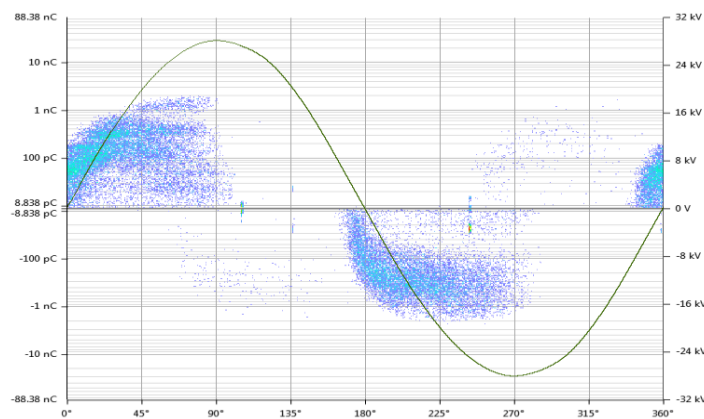
*Figure 2 - NL camera with real time discharge detection*

## 2 Measurements with the NL camera

Three cases were depicted here where two measurement has been taken along with the electrical partial discharge measurement & another one at site during online monitoring.

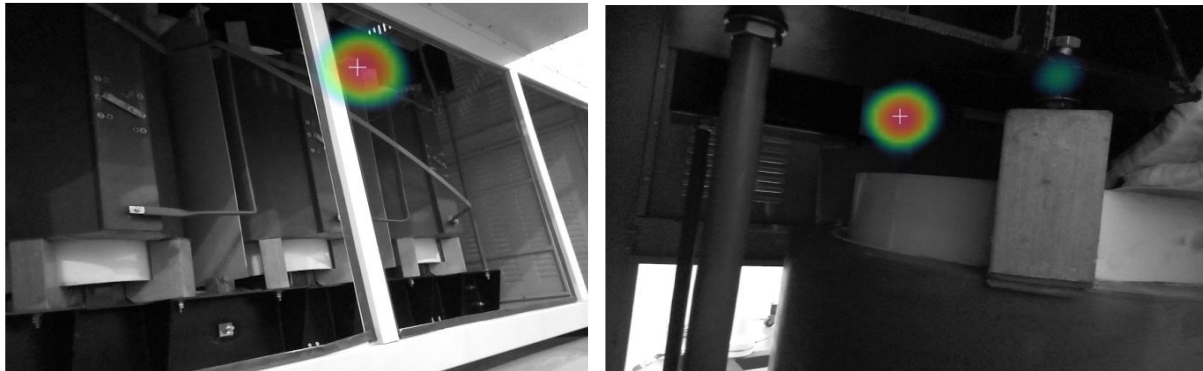
### 2.1 Case study of 5MVA dry type transformer

5MVA, 11/0.415 kV dry type transformer with enclosure which was newly manufactured shows the partial discharge activities in the B phase winding during laboratory measurement.

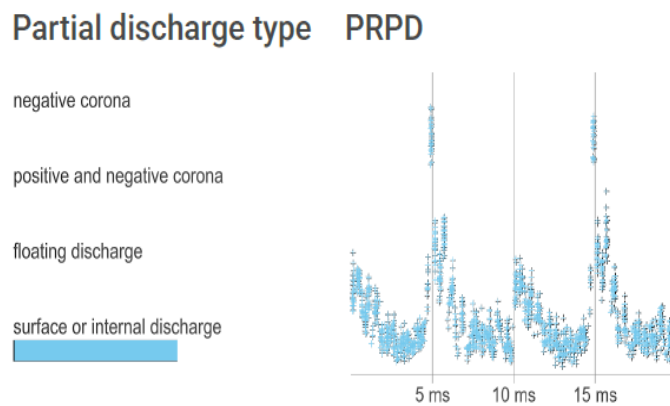


**Figure 3 - PRPD pattern for dry type transformer shows 1.5 nC of PD**

NL camera was utilized for identifying the probable region of discharges. By opening the side covers of enclosure the measurement was taken with the help of NL camera & it shows the probable location of discharges on upper part of B-phase winding.



*Figure 4 - Location of discharges identified by the NL camera*

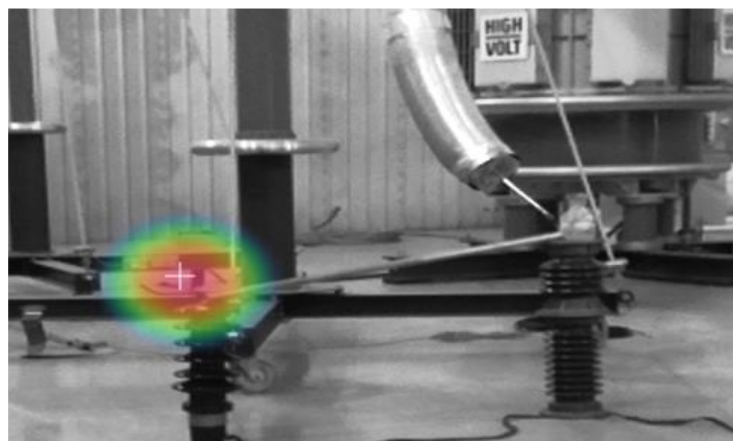


*Figure 5 - Analysis of discharges & PRPD pattern observed from the acoustic camera*

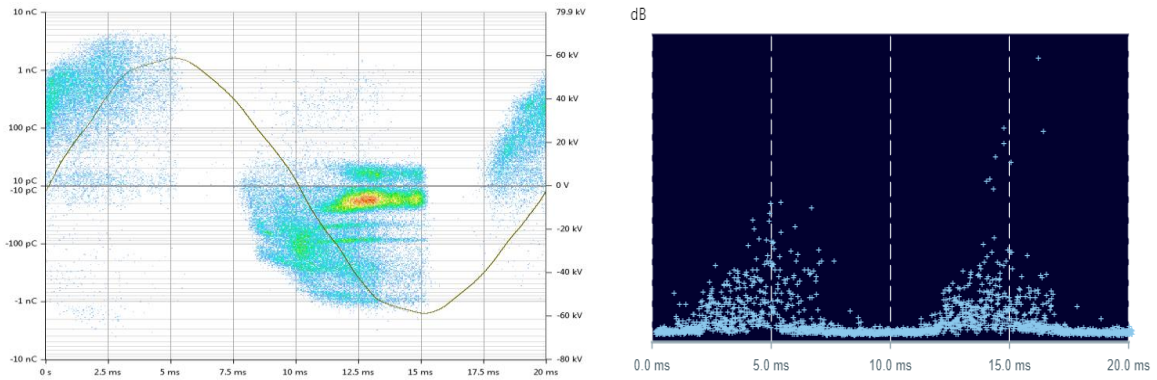
The discharges analysis of NL camera shows the internal kind of discharges in the transformer which co-relates with the electrical partial discharge measurement.

## 2.2 Case study of 66 kV insulator

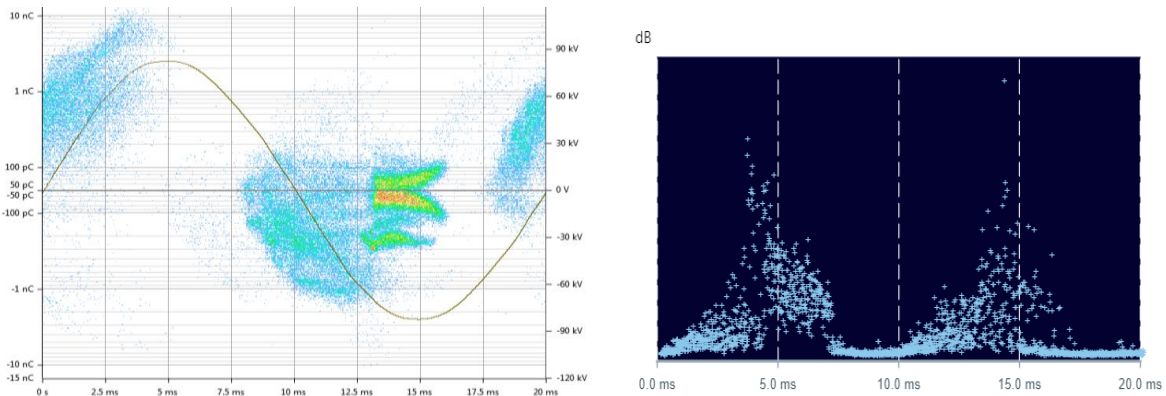
One 66 kV porcelain insulator was subjected to accelerated surface ageing to study the effectiveness the NL camera for online monitoring of insulator.



*Figure 6 - Measurement of 66 kV insulator to study the effect of surface leakage*



**Figure 7 - Comparison of electrical PD (3400pC) & by NL camera (18.4 dB) at 40 kV**

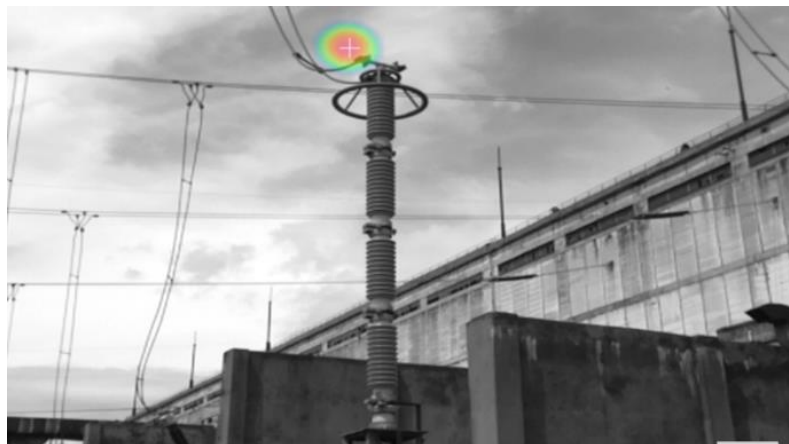


**Figure 8 - Comparison of electrical PD (8000 pC) & by NL camera (35 dB) at 55 kV**

The analysis of the discharges by NL camera shows that the discharges are from surface discharges which is generated due accelerated ageing in salt fog chambers.

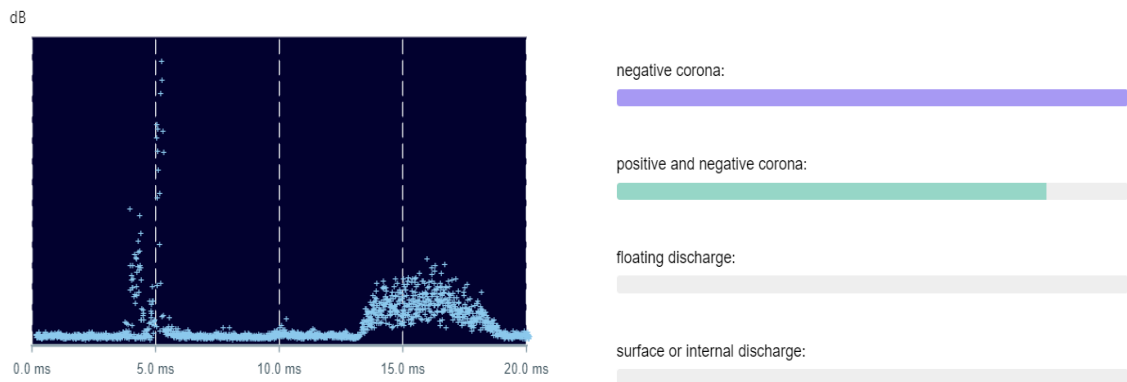
### 2.3 Case study of 400 kV Lightning Arrestor

In filed condition measurement was taken on the 400kV LA.



**Figure 9 - Measurement on 400kV LA**

The measurement shows that the discharges are observed at the connection point of LA due to corona effect.



**Figure 10 - PRPD pattern on NL camera & analysis shows that the discharges of corona**

Since the most of the discharges generated are due to the corona effect as discharge pattern is mainly concentrated at positive & negative peak of PRPD pattern.

### 3 Conclusion

From the above depicted cases discharge detection using this technique of NL camera is very useful tool for online condition monitoring. First case of transformer shows that the discharges identified the NL camera are in line with the direct method of partial discharges. Second case gives the sensitivity of this method, as the magnitude of pC in direct measurement increases the discharge level in online camera detection also increases. While the third case study shows that identification of type of discharges are also feasible which prevent any false alarm. Overall the acoustic signal detection along with the optical image gives good idea about the condition of the insulation & this method can be prove as one of the best possible tool to monitor the outdoor switchyard equipment.

## Bibliography

- [1] Hussain, MM, Farokhi, S, McMeekin, SG & Farzaneh, M 2017, 'Mechanism of saline deposition and surface flashover on outdoor insulators near coastal areas part II: impact of various environment stresses', *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 24, no. 2, pp. 1068-1076. <https://doi.org/10.1109/TDEI.2017.006386>.
- [2] S. Huafeng, D. J. Zhidong, C. G. Zhicheng, and L. Licheng, "Mechanism of contaminant accumulation and flashover of insulator in heavily polluted coastal area," *IEEE Trans. Dielectr. Electr. Insul.*, Vol. 17, No. 5, pp. 1635-1641, 2010.
- [3] A. Banik, S. Dalai and B. Chatterjee, "Condition monitoring of overhead line insulator by measuring surface leakage current," 2014 Annual IEEE India Conference (INDICON), 2014, pp. 1-5, doi: 10.1109/INDICON.2014.7030540
- [4] Ha H., Han S., Lee J. Fault detection on transmission lines using a microphone array and an infrared thermal imaging camera. *IEEE Trans. Instrum. Meas.* 2012;61:267–275. doi: 10.1109/TIM.2011.2159322.
- [5] Park K.C., Motai Y., Yoon J.R. Acoustic fault detection technique for high-power insulators. *IEEE Trans. Ind. Electron.* 2017;64:9699–9708. doi: 10.1109/TIE.2017.2716862.
- [6] Hussain, M.M.; Farokhi, S.; McMeekin, S.; Farzaneh, M. Mechanism of saline deposition and surface flashover on outdoor insulators near coastal areas part II: Impact of various environment stresses. *IEEE Trans. Dielectric*
- [7] IEC 62478:2016, "Measurement of partial discharges by electromagnetic and acoustic methods".
- [8] IEEE 1434: 2014, "IEEE recommended Practices and Requirements for Online PD Measurements".
- [9] Markalous, S.M.; Tenbohlen, S.; Feser, K. Detection and location of partial discharges in power transformers using acoustic and electromagnetic signals. *IEEE Trans. Dielectr. Electr. Insul.* 2008, 15, 1576–1583.
- [10] IEC 60270:2000, "High-voltage test techniques - Partial discharge measurements"
- [11] IS 9000-11: Basic environmental testing procedures for electronic and electrical items : Salt mist test