Partial Discharge Detection During Electrical Aging of Generator Bar Using Acoustic Technique

S. Ahmadi
Power and Water University of Technology (PWUT), Tehran, Iran
siavash.ahmadi2011@yahoo.com

M.R. Naghashan
Power and Water University of Technology (PWUT) Tehran, Iran
naghashan@PWUT.ac.ir

M. Shadmand
Pars Generator co.
MAPNA, Tehran, Iran

Abstract— **Partial discharge is of the most powerful and important means to diagnose insulation health in generator bar. There are many methods available to detect the PD activity in generator bar. Acoustic detection as a partial discharge detection method has wide range of applications. Acoustic method versus electrical detection methods has several advantages such as immunity against electromagnetic fields.**

In this paper, an air-cooled generator bar (15.75 kV nominal voltage) is aged under electrical stress. Electrical aging test is carried out according to IEEE 1553-2002. Acoustic signals due to partial discharge during electrical aging of generator bar within 500 hours are recorded using acoustic technique every day. In this method, two points of the bar as test points are considered. The first point is located on one of the lateral side of generator bar while the other point is located on the bar centre. Acoustic sensor output is sent to an 80MHz PC-based A/D card and is filtered at the maximum frequency band-width of the sensor. Acoustic signal variations are investigated during aging process. The variations show that acoustic signal amplitude due to partial discharge increases at the first days, then collapses and remain constant during the aging.

Keywords-generator bar; aging; partial discharge; acoustic;

I. INTRODUCTION *(HEADING 1)*

Undoubtedly, power plant generators which play principle rule in the generation process are of the most important parts of power systems. According to high price of these assets and their major role in power system stability, the necessity of using diagnosis tests is inevitable [1]. In the meantime of generation operation, not only proper actions should be done to estimate remaining the life time but also technical planning strategies should be carried out to assess and remove the faults. Partial discharge (PD) test as one of the most important diagnosis tests can provide useful information for operators and generator insulation system designers. A PD phenomenon as a physical phenomenon which occurs inside insulation has several effects. Regarding to the fact that each discharge occurrence accompanies with propagation of electrical, acoustic and optic signals [2], [3]; hence, acoustic detection is considered as a PD detection method. From theoretical and practical viewpoints in detection and localization of PD, acoustic detection is easier than electrical detection methods [4].

Authors of [5] localize PD inside generator bar using acoustic methods and validate their approach by creating artificial voids. Zhu et al in [6] measure PD signals during thermal cycling test using acoustic method and assess groundwall insulation delamination. Hao et al in [7] compare acoustic test results with dielectric losses coefficient (tanδ) test and microscopic observations. In [8] PD signals are detected using acoustic method and de-noised using wavelet analysis. Hence, Acoustic methods as PD detection method have several abilities.

In this paper, a generator bar is aged under electrical stress, PD signals are detected using acoustic method, and obtained results are compared with tanδ results.

II. TEST SAMPLE AND EXPERIMENTAL SETUP

The bar used in this experiment belongs to a 200MVA, 15.75kV generator. The length of slot portion is 642cm. the conductor has 104 strands which locate in two columns with 360 degrees transposition. The bar cross section area is 26*112 mm^2. The insulation is class-F resin-rich type.

The semiconductor surface in slot portion is covered by aluminum foils, during tanδ test both sides of its guard area are connected to ground.

III. TEST PROCEDURE

In this experiment a generator bar is aged electrically. Bar temperature is measured by two thermometers. These thermometers measure external surface temperature. Bar temperature during aging process reaches at 54 degrees of centigrade approximately due to dielectric losses (around 20 degrees more than ambient temperature). Moreover, Insulation resistance test is carried out before aging and the results is modified into 40oC. The results satisfy the requirements of IEEE std 43-2000 [9].

According to IEEE std 1553 [10] the applied voltage is 34.2kV during electrical aging and minimum time to failure under electrical stress is 400 hours.

Two parts of the bar are selected. One of them is located near the slot portion in one end of the bar (called first point) while the other is located at the middle of slot portion (called middle point). Acoustic sensor is moved slightly in the selected parts. This procedure is done on several points until maximum amplitude is observed. The points in which the maximum amplitude is obtained are marked. During the aging intervals, the sensor is located at the marked points and signals are recorded. An 80Ms/sec, A/D sampling card is used to transfer data to PC. PD test is carried out at 9.2kV. The peak value of obtained signal at marked points is recorded as acoustic signal amplitude due to PD.

IV. Results and Discussions

The detected acoustic signal wave shape at beginning and middle points in first day are shown in fig. 1 and fig. 2, respectively. The detected signals are investigated in frequency domain. As can be seen from Fig. 3, the signals have two proper responses in 0-10kHz and 5.6-5.9MHz bandwidths, the later band is used for the data filtering because the former is located at audition range and the probability of external noise interferences is high. Fig. 4 and Fig. 5 illustrate filtered signal in 5.6-5.9MHz band.

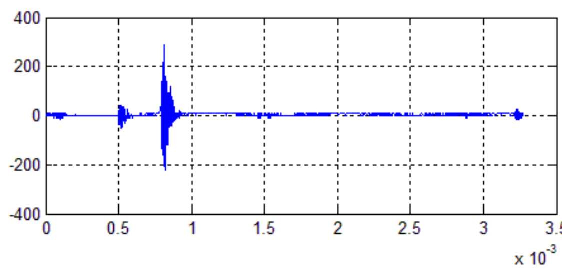

Figure 1. Detected acoustic signal wave shape at beginning point in first day

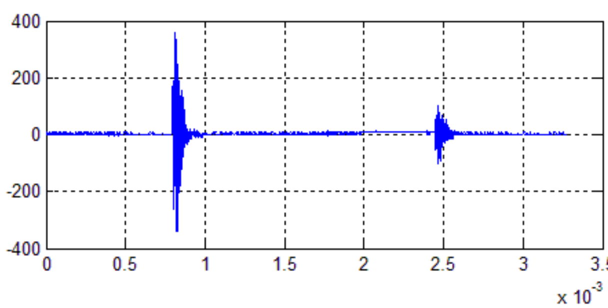

Figure 2. Detected acoustic signal wave shape at middle point in first day

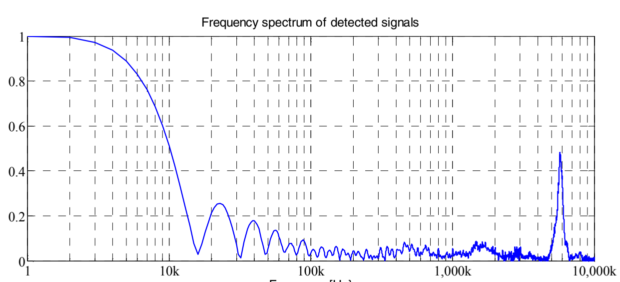

Figure 3. Representation of obtained signals in frequency domain

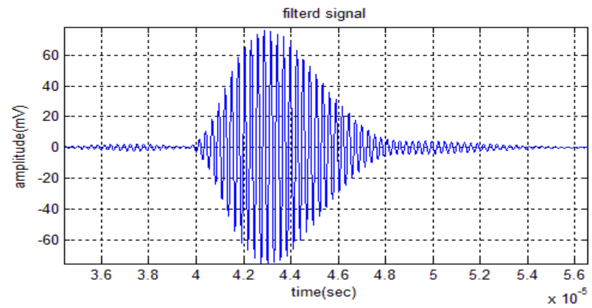

Figure 4. Filtered acoustic signal using band pass filter with 0.3MHz bandwidth at first point in first day

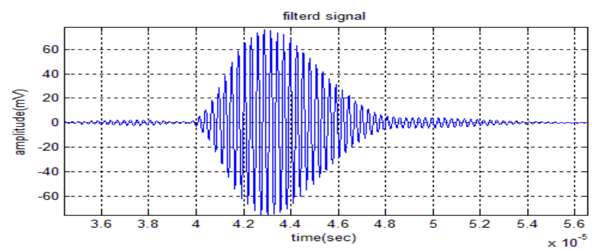

Figure 5. Filtered acoustic signal using band pass filter with 0.3MHz bandwidth at middle point in first day

The maximum value of each signal is recorded as acoustic signal amplitude due to PD. Fig. 6 and fig. 7 show variations of PD signal amplitude during aging at beginning and middle points, respectively.

As is illustrated by Fig. 6 and Fig. 7, acoustic signal amplitude increases in initial days. Nevertheless, the continuation of aging process is led to dramatically decreasing of amplitude and after that it reaches its plateau approximately. The decrease of PD amplitude may be due to several reasons, namely: charging of voids surface, voids carbonizations due to severe applied electrical field, variations of gas pressure inside the voids, and variation of PD signals from impulse form to semi-rectangular and Townsend forms.

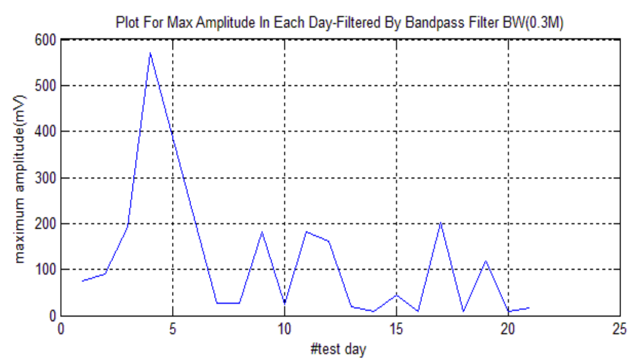

Figure 6. Variations of PD amplitude during aging at first point. Filter bandwidth is 0.3MHz

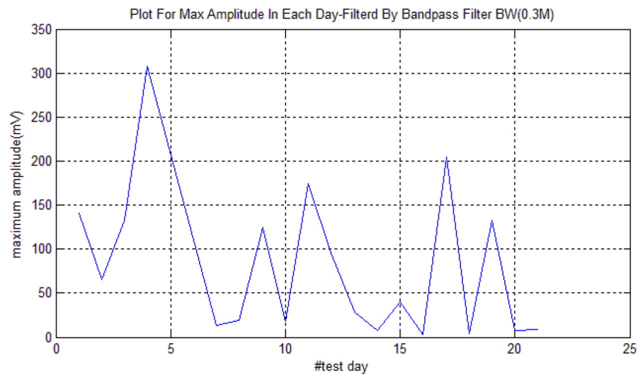

Figure 7. Variations of PD amplitude during aging at middle point. Filter bandwidth is 0.3MHz

Fig. 8 shows dielectric losses coefficient (tanδ) before and after aging process. As can be seen after 500 hours of aging, tanδ increases significantly.

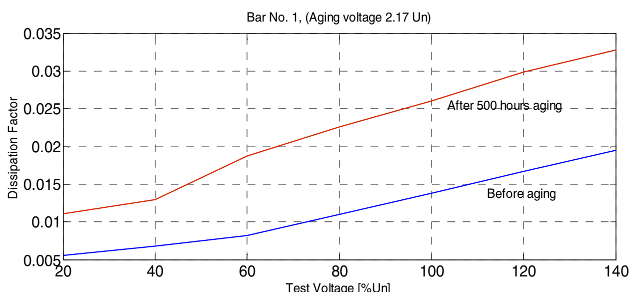

Figure 8. variation of tanδ versus voltage before and after 500 hours of aging

Conclusion

In this paper, PD signals are detected during electrical aging of a generator bar using acoustic sensor and the obtained results are compared with results of tanδ test. The results show that the trend of PD amplitude is increased in the initial days of aging, after that it experiences a decrease dramatically, and finally it reaches its approximate plateau. It is shown that, besides the simplicity of acoustic detection method compared with electrical detection methods, it provides proper and reliable results.

REFERENCES

[1] G. C. Stone, E. A. Boulter, I. Culbert, and H. Dhirani, "Electrical Insulation for Rotating Machines," IEEE Press, 2004, ISBN 0-471-44506-1.

[2] R.Schwarz, T.Judendorfer, M.Muhr, "Review of Partial Discharge Monitoring techniques used in High Voltage Equipment",2008 Annual Report Conference on Electrical Insulation Dielectric Phenomena

[3] R.Bartnikas, "Partial Discharge, Their Mechanism, Detection, and Measurement", IEEE Transactions on Dielectrics and Electrical Insulation Vol. 9 No. 5, October 2002

[4] L. E. Lundgaard, "Partial Discharge-Part XIII:Acoustic Partial Discharge Detection-Fundamental Considerations", IEEE Electrical Insulation Magazine July/ August 1992 - Vo1.8, No.4.

[5] R. Bozzo, F. Guastavino, G. Guerra, " PD Detection and Localization by means of Acoustic Measurements on Hydogenerator Stator Bars", IEEE Transactions on Dielectrics and Electrical Insulation Vol. 2 No. 4, August 1995

[6] H. Zhu and D. Kung, "Acoustic Monitoring of Insulation Delaminations during Thermal Cycling Tests on a Stator Bar", EIC 2009

[7] Y.Hao, H.Xie, G.Wang, "Assessment of Insulation Condition of Generator Stator Bars Based on Velocity of Ultrasonic Waves", IEEE Transactions on Dielectrics and Electrical Insulation Vol. 10, No. 3; June 2003

[8] L.Chen, W.Lin, T.Tsao, Y.Lin, "Study of Partial Discharge Measurement in Power Equipment Using Acoustic Technique and Wavelet Transform", IEEE Transaction on Power Delivery, VOL. 22, NO. 3, JULY 2007 1575

[9] "IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery", IEEE Std 43-2000(R2006)

[10] "IEEE Trial-Use Standard for Voltage-Endurance Testing of Form-Wound Coils and Bars for Hydrogenerators", IEEE Std 1553-2002 (R2007)