ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

Audible Noise Characteristics of 765 KV Insulator

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ABSTRACT: This paper represents the analysis of Audible Noise characteristics for 765 kV post insulator and string insulator within the frequency range of 10kHz -30 MHz. Now a day the need of power has been increasing day to day this makes the utilities to build up cost effective transmission lines without any impact on living beings and on the environment. To transmit power to long distances it necessary to use higher transmission voltages. At higher voltages, the effect of Audible Noise is very severe. Audible Noise caused by the high rated equipment's in substations or in transmission lines is the factor that has a huge impact on people. Hence great care has to be taken at the line design stage that not to produce unacceptable audible noise. Pre-determination of Audible Noise thus become important at the transmission design stage itself. The proposed work includes the evaluation of Audible Noise parameters at different test voltages and under various positions of test samples by employing standard substation equipment in the laboratory. The data generated will be useful as a guide for the new lines and substations and a relation between Audible Noise and voltage gradient was obtained for the given test voltages**.**

KEYWORDS:sound pressure level, corona loss, Audible Noise, Post insulator, string insulator, power transformers.

I.INTRODUCTION

Now a day electrical market are rapidly changing the rules of power distribution, increasing cost pressure on utilities and network operators in the world over. This, in turn putting pressure on operators and substation suppliers to find suitable means for reducing cost without satisfying quality. The definition of their function is to connect different networks and transfer electrical energy with a good margin of safety. Hence the power companies are forming grids to meet the required amount of power transfer. With this the electrical companies developed well versed engineered transmission lines and substations around the world. The materials used in the transmission lines are conductors, insulators, corona rings, conductor hardware, spacers, dampers and conductor sleeves etc. among all insulators plays a vital role in substation and in transmission lines. Bulk power is possible economically with Extra High Voltage (EHV) and Ultra High Voltage (UHV) lines. With thesehigh voltages the insulators placed in lines or in substation are affected because of Radio Noise, Audible Noise, leakage current, flashover voltage and Pollution of the that insulator. Hence to predict the audible noise characteristics for an insulator is important in the design of insulators which are used for high ultra-voltages. In transmission and distribution,insulators play an important role and are placed in different configurations like horizontal, vertical, single I, double II, single V, double V, and Quad tension positions. In this present work we measured the audible noise generated by the insulators and transformers when they are energized by different high voltages under different configurations to obtain a relation between the voltage gradient and audible noise generated. Many researchers studied the performance of audible noise produced from transformers, conductors, from transmission lines and from insulators and stated their valuable conclusions.

The audible noise produced from the transformers is due to many reasons in [1] RuchiNegi and Prateeksingh observed the noise produced from the transformers and stated that, the noise is due to improper design, wiring and improper grounding. In [2] and experimental study on transmission line with the help of noise meter is done and obtained a method to know the inception of corona. In 2009 an observation was made by Dernfalk and Gutman[3] by some voltage tests and concluded that the insulator like glass cap and pin which are covered by cement around the pin are evident for generation of noise and the noise is expected to be higher in wet condition. Edger,Taylor and Vernon [4] done laboratory tests to estimate the Audible noise generated and corona from high voltage extra high voltage

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transmission lines, substation conductors for the ratings 345 kV and 765kV, then from the results stated that audible noise increases with the number of sub-conductors in a bundle. Later on Gerhard W. Juette and Luciano [5] has done a research on radio noise currents and audible noise generated from the bundle conductors and obtained a relation between radio noise and audible noise of conductors. M.G.Comber and R.Cortina [6] also measured audible noise from individual sub-conductors in a transmission line and concluded the same as Gerhard that the audible noise generated can be calculated through the knowledge of generation of individual sub-conductors in the bundle. And also stated that the noise generated from each sub-conductor are different.N.Kolcio and J.Diplacido, R.J.Haas and D.K.Nichols [7] observed the noise interference at two generating stations located near 765kV lines of American power. A comparison was made between the two operating lines when energized at705 kV, 725 kV, 750 kV and 760 kV. Fromtheir results it was shown that, the average audible noise generated in rain are 17-19 dBA higher than that in fair weather condition, while the radio noise 15-17 dB (QP at 1MHz). In the year 1994 Vernon L.Chartier, David E.Blair, DouglasJ.Lamb and Richard D.Stearns [8] observed the effect of bundle orientation on audible and radio noise. The RN and AN from 4 Bunting and 4 trapezoidal conductors either in diamond or square and the same oriented in vee or inverted vee either horizontal or vertical positions. And concluded that, no consistent change is observed in audible and radio noise under artificial rain conditions in conventional bunting or in trapezoidal.

Audible noise of the filter capacitors in HVDC converter station is severe as loud as the converter transformer and it is reduced by a micro perforated-panel absorber and statistical investigations of Radio Interference on 750 kV Transmission Lines are done [9-`10]. Hence audible noise generating from the insulator strings is important to be consider and the data on the levels of AN produced from the insulator at different high voltages in different positions is not provided in detail. With this experience the present scope of work covers study and evaluation of audible noise generation from HV equipment at different environmental conditions. Pre-determination of AN from the post insulator, insulator string and from the power transformers, thus becomes importance at the transmission line design stage itself. From these measurements we can reduce arcing of a transformer there by reducing the AN level, like replacement of old transformers with low-noise units, simple open-roof barriers, 4-sided sound enclosure, oil containment pits, Active sound cancellation using an amplifier and speaker system etc.

II.EXPERIMENTAL SETUP

Test Specimen: In this paper a 765kV Solid core Post Insulator and Insulator String were taken with a height of 5700mm. The Specific Creepage distance of the test specimen is 25mm/kV and the technical parameters of the test specimen are shown in table 1.

TABLE I
The Technical Parameters of the Test Specimen

Technical Values	Voltage(KV)
Wet power frequency withstand voltage	830
Dry power frequency flash over voltage	860
Impulse withstand voltage (1.2/50 micro sec)	2450 kVp
Impulse flash over voltage (1.2/50 micro sec)	2806 kVp
Switching surge voltage(250/2500 micro sec)	1550 kVp

In this work the specimen is tested in different positions like single I, double II, single V, double V and Quad tension positions to measure Audible Noise levels with respect to the system voltages. In this test the test specimen is connected in vertical position by connecting high voltage end to one end of the string and the other to the ground terminal. Figure 1 shows the specimen arrangement of 765 kV double II (suspension) string during the test condition.

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Fig.1.Test specimen arrangement

Test Meter: Audible Noise meter is used to measure the audible noise produced from the insulators. In this work the Audible noise for the insulator is measured from the CEL-414/3C[11] precision Impulse Sound Level Meter, which satisfies the requirements of the international standard IEC 651 Type1.1 for impulse sound level in the range from 20 dB(A) to 140 dB (A) at frequencies between 3.5 Hz to 20 kHz with the microphone supplied. The human ear is frequency dependent, and is most sensitive between 1 and 5 kHz. The A-weighted filter network with a response close to the human ear was introduced to measure annoyance. The unit for a sound level measured with an A-Weighted filter is dBA and is referred to 20 μPa. Audible noise produced by the string is therefore expressed in dBA.

III.EXPERIMENTAL RESULT AND DISCUSSION

In this paper the audible noise was measured from the 765 kV insulators in three different cases. In the first case AN was measured for 765 kV post insulator at different standard test voltages, in this case the noise meter was placed at 15m from the mid-span of the line. The specified test voltage related to the voltage is to be applied to the insulator in normal service, that is, equal to the highest system voltage divided by √3. The insulator is mounted for test closely imitating service conditions. As the noise level is affected by dust settling on the insulator, it is permitted to wipe the insulator with a clean cloth before the test. Here a voltage 10 per cent higher than the specified test voltage shall be applied to the test object under test and maintained for at least 5 minutes. The voltage shall then be decreased by steps down to 30 per cent of the specified test voltage, raised again by steps to the initial value and finally decreased by steps to the 30 per cent value. At each step, audible noise levels as recorded shall be plotted versus the applied voltage, the curve so obtained is the audible noise characteristic of the insulator. Each voltage step shall be approximately 10 percent of the specified test voltage [12]. The results of Sound pressure level (SPL) is twenty times the logarithm to the base ten of the measured sound pressure (p) to a reference pressure (p_0) of20micro-Pascal (μpa). The SPL measurement is done by SPL meter also called Audible Noise Meter [8]. The sound levels are expressed in decibels (dB) by selecting A weighting function in Audible Noise meter and the noise is measured at a distance of 15m from the source of corona then sound levels (AN) from the energized test samples were measured. The instantaneous sound pressure level displays on the digital portion of the display, this display is updated in every 500ms. The highest sound level is noted during the measuring period and is shown on the digital when MAX is selected [8].

TABLE II
Results of RN and AN at different test voltages

Standard test voltage	Test Voltage kV(rms)	Audible noise measured dB(A)
1.1Ur/√3	508	54.9
1.0Ur/√3	462	52
0.9Ur/√3	416	50
0.8Ur/√3	370	48
0.7 Ur /√3	324	45
0.6 Ur √3	278	45
0.5 Ur √3	232	45
0.4 Ur √3	186	45
0.3Ur √3	140	45
Ur=800 kV		

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Vol. 4, Issue 11, November 2015

Table II shows the results of Audible Noise measured from the 765 kV post insulator by keeping the noise meter at 15m from the corona source. With the measured values a graph is plotted by using Excel sheet. From the measured data it is clear that for the test voltages at 500 kV and below the ANis in between 45 to 50 dB. Hence it may increase for higher and ultra-high voltages which may damage the human year for long time appearance of sound.

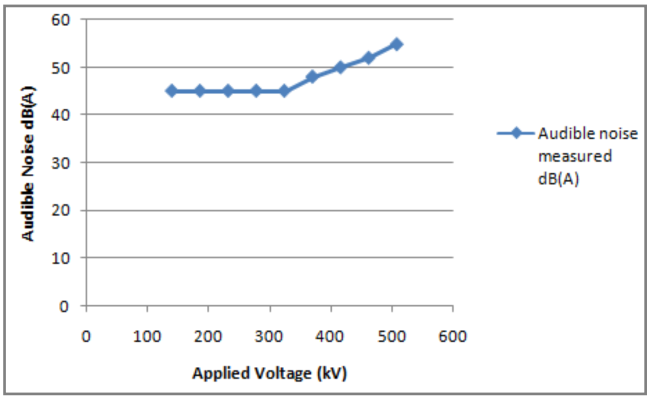

Fig.2. AN characteristics of 765 kV post insulator

Now from the results of 765kV insulator the trend lines and relevant equation were drawn with the help of MS excel program for the values Audible Noise shown in table II then from fig.2 the equation for AN is obtained and shown in equation 1.this equation gives the relation between audible noise and the test voltage.

AN $$Y_{an} = 21.039\, X^{0.1433} \qquad (1)$$

Here y_{an}isAudible Noise in dB (A) and X is the voltage in kV.

From this equation an expected value of audible noise can be known for the applied test voltage as this is used particularly in the design of insulators which are used for ultra-high voltages.

In the second case the Audible Noise is measured for 765 kV insulatorstring at a distance of 15m from the corona source under different test voltages in various positions of the insulator they are Single I, Double II, Single V, Double V and Quad Tension and the results are tabulated in the table III . In this case the string is placed in vertical position and one end is connected to high voltage and the other end to ground terminal. Audible noise meter is placed at 15 m away from the insulator then under different high voltages the noise is measured by using the meter provided in different test positions of insulator. From the measured data it is observed that, the noise generated from the insulators in different under different high voltages. Among them the noise is high in lightning impulse flashover condition that is 92 dB. Then the voltage gradient is calculated from the voltage applied and from the specifications of insulator string. Then a relation was obtained between the voltage gradient and audible noise. The calculation of voltage gradient is as follows.

Voltage gradient: $\frac{CU}{\epsilon 0 \pi ND}$kV/cm

Where Capacitance of the conductor (C) = $\frac{2\pi\epsilon 0}{\ln\frac{2H}{Req}}$Farads

U: Test Voltage (kV rms)
N: Number of conductors = 4 no's
d: overall diameter of the conductor = 3.17cm
H: height of the conductor above from ground=1120 cm
Equivalent radius of the bundle (Req) =$(N.r.R^{N-1})^{1/N}$(cm)
r: radius of sub conductors= 1.75 cm

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Radius of the bundle (R) $= \frac{B}{2\sin\frac{\pi}{N}}$ (cm)

B: Bundle Spacing= 45.7cm

TABLE III

Results of Audible Noise measured for 765Kvpost insulator

Test voltage	765kv strings	Voltage gradient kv (peak)/cm	Audible noise dB(A)
PFWS-830 kVrms	Single I	28.3	63.8
	Double II		64.3
	Single V		64.0
	Double V		64.0
	Quad Tension		64.8
SIWS-1550 kV peak	Single I	37.4	61.0
	Double II		65.3
	Single V		57.3
	Double V		67.2
	Quad Tension		62.4
LIWS-2450kV peak	Single I	59.1	67.9
	Double II		68.1
	Single V		68.0
	Double V		67.0
	Quad tension		65.8
LI-Flashover Average flashover value-2806 kV peak	Single I	67.6	90.2
	Double II		92.6
	Single V		91.7
	Double V		96.1
	Quad tension		90.0

Now for the results of audible noise of table III the average values are calculated to estimate the average audible noise in each high voltage. The average values are tabulated in table IV and from this average values it is noticed that for the post insulator the average noise is between 40 to 55 dB but for the string the noise is increased by 10 dB in power frequency high voltage. While for lighting impulse it is increased by 20 dB and for lightning flash over it is doubled. This noise is very harmful to the living beings and human beings nearby.

TABLE IV

Average Values of Table III

Test Voltage	Voltage gradient kV(peak) / cm	Audible Noise dB(A)
PFWS- 830 kV (rms)	28.3	64.18
S IWS- 1550 kV peak	37.4	62.66
LI WS -2450 kV peak	59.1	67.36
LI –Flashover Average flash over value – 2806kV peak	67.6	92.12

A graph is plotted between Audible Noise and Voltage gradient from the results of table III by using Excel sheet and is shown in fig.3.

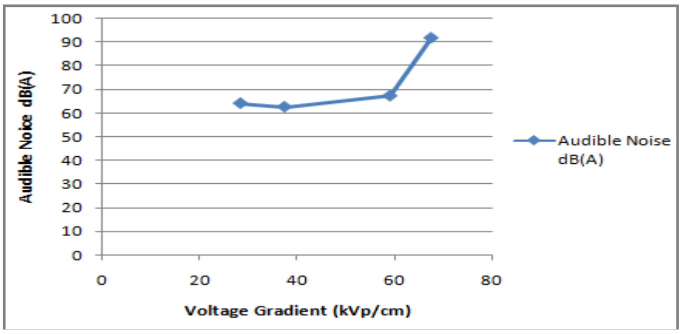

Fig.3. AN characteristics of 765 kV string insulators

From fig 3 also it is clear that the noise level is in between the 60 to 70 dB, only in flashover condition it is greater than 90 dB. Then fromthe characteristics of Audible Noise we can get the relation between the test voltage and audible noise and this relation is shown in equation 2.

$$Y = 0.5915X + 43.13 \qquad (2)$$

Here y is the audible Noise in dB (A) and X is voltage gradient in KV (peak/cm).From this we can get the AN levels during the power frequency voltage withstand, switching Impulse voltage withstand, Lightning Impulse voltage withstand and Flashover.

In the third case the noise was measured from the power transformers because the two major sources of noise within a substation are continuous from power transformers and reactors and momentary noise due to the operation of circuit breakers. The most significant noise is from transformers, the transformers located in existing substations are noisy. Generally transformer noise should be slightly audible during the quietest period and in audible during the rest of the day when people are normally active [13]. Here we measured the Audible noise for different ratings of power transformers. Here the Audible Nose is measured from the power transformer at 15mt from the corona source and the results are shown in table V.

TABLE V
Results of AN measured from power transformers

	Transformer rating	Audible noise measured in dB (A)
1.	16MVA, 33/11 kV	64.9
2.	16MVA, 33/11 KV	63.9
3.	25MVA, 110/22 KV	58.0
4.	25MVA, 110/33 KV	71.5
5.	16MVA, 110/11 KV	64.0
6.	16MVA, 110/11 KV	67.8
7.	50MVA, 110/33 KV	71.0
8.	16MVA, 110/112 V	71.6
9.	25MVA, 110/22 KV	68.67
10.	16MVA, 110/22 KV	62.25
11.	16MVA, 110/11 KV	64.87

The noise is measured from different transformers of different ratings with the help of audible noise meter. From the data in table V it is observed that the Audible noise from substation transformers will be in between 55 and 75 dB (A) in any operating condition. It is also observed that for 110/22 kV transformer with 25 MVA the noise produced is approximately 58 but in other weather condition it is increased to 68.67 dB because it depends on the atmospheric conditions even though same rating transformers. Hence the noise produced from any electrical equipment depends on the temperature and weather conditions.

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IV.CONCLUSION

In this paper Audible Noise were measured for 765 kV post insulator and 765kV Insulator String at a distance of 15mt away from the corona source. From these experimental results a relation between AN for a test voltage is derived. And for 765 kV string the noise is also measured under different high voltages along with voltage gradients, from this it is observed that the AN value increases with the voltage gradient and the maximum noise is observed in lightning impulse flashover condition, and from the measured data the relation between AN and voltage gradient is derived. This methodology used will help in checking the ANlevels of the equipment before placing them in transmission lines. And it is also observed that Power transformers can produce Noise above 55 dB (A) in service and the maximum noise produced in working condition is 75 dB. The data obtained will be useful for the academics and power sector.

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