Noise Dose Emitted from Different Electrical Machines Compared

Tirtharaj Sen, Pijush Kanti Bhattacharjee, Debamalya Banerjee, Bijan Sarkar

Abstract*— This paper deals with the study and comparison of noise dose emitted from different electrical machines. The study has been done in an electrical machine laboratory. Readings of noise parameters are taken from different machines using a noise dosimeter and the different noise related variables such as Leq (Equivalent continuous A-weighted sound level), LAV (Average sound level), LAE (Sound exposure level), TWA (Time weighted average) are compared for different ac and dc machines. Nomographic technique based on graphical analysis is used for finding out percentage noise dose and comparing that with the data collected from dosimeter. This study gives a complete measurement of noise levels and its parameters for different electrical machines ac and dc types, and hence it is a source to detect mechanical faults of the machines which are causing the noise produced. Also mechanical faults of the electrical machines are identified by analysis the frequency of noise emitting sound from the machines. These techniques are used for safeguarding the machines as well as environmental pollution.

Index Terms*— Electrical Machines, Frequency of Noise Emitting Sound, Noise Dose, Noise Dosimeter, Noise Related Parameters, Peak Exceedance Level.

I. INTRODUCTION

Noise is very physical and noticeable to the most human beings. Questionnaire investigations in an industrial plants show that, the workers usually single out noise as the unsolved important problem [1]-[18]. This is totally expected, because of comparing with many other ergonomic problems; noise is very obvious and concrete.

In the dBA scale, which has achieved widespread use in the industries, noise measurement is done, since in this scale weighting function approximates the sensitivity of the human ear. To calculate the sound pressure level (Lp, in decibels), the formula is used: $Lp = 20\log(P/P0)$, Where P is the root mean square (rms) sound pressure and P0 is the reference sound pressure (0.00002 N-m-2).

There are four different aspects that can make noise unacceptable in the working environment.

1. Noise can cause hearing loss.
2. Noise can affect performance and productivity.
3. Noise can create annoying.
4. Noise can interfere with spoken communication.

The effects of noise may be unnoticed instantaneously unlike other contaminant agents and its accumulation can lead to a dangerous harmful effects to human as well as machines. In common use, the word noise means any unwanted sound. Noise dose may be given in terms of a value relative to unity or 100% of an “acceptable” amount of noise. Different parameters related to noise dose are Leq (Equivalent continuous A-weighted sound level), LAV (Average sound level), LAE (Sound exposure level), TWA (Time weighted average) etc.

Leq is the constant sound level that, in a given time period would convey the same sound energy as the actual time varying A-weighted sound level. LAE is defined as that level which lasting for one second has the same acoustic energy as a given noise event lasting for a period of time T. LAV is defined as the total energy averaged over the total time. TWA is the noise that is weighted over a certain amount of time such as 8 hours (for machine noise). Noise dose readings [1]-[16] has been taken for different dc machines such as dc shunt motor, dc generator and ac machines like wound rotor induction motor, squirrel cage induction motor, single phase induction motor and synchronous motor etc. It is very important to measure noise dose as well as different parameters related to noise dose or sound pressure level. The machines which produce noise levels as high as 120 dBA or more violates the rules of National Fire Protection Association guidelines (1993 A.D.). The legislation describe on OSHA (1992 A.D.) is that, when a human is exposed to 90 dBA for 8 hrs, he has a 100 percent dose. So, 100 percent noise dose is always representing the criterion dose whatever may be the duration of measurement [6]-[10].

1.1 Instrument Used: Brüel & Kjær made (Noise) Dosimeter Type 4444, a robust and lightweight instrument, is used for assessment and recording of noise levels associated with Electrical Machines.

Specifications of the Noise Dosimeter conform to the following National and International Standards:

IEC61252, ANSI S1.25, IEC60651.1979 Type 2a, IEC60804.2000 Type 2a, ANSIS1.4.1983 Type S(1) ANSIS1.43.1997. The Supplied Microphone has the following specification:

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Type: 1/4″ Microphone with Integral Cable Connector: 5-pin LEMO. The Measurement Control has the specification as stated herein:
Manual Control: using keys for Start/Pause/Continue and Stop. After the Start key is pressed, measurement starts and the clock reaches 00 seconds.
The Measuring Ranges are as follows:
Linearity and Indicator Ranges at 4 kHz (IEC60804): 30.100: 43b.100 dB (A and C), 50.120: 50.120 dB (A and C), 70.140: 70.140 dB (A and C).
The Peak Range is as below:
C-weighted or Linear Peak over the top 40 dB of each measurement range: 30.100: 63.103 dB Peak, 50.120: 83.123 dB Peak, 70.140: 103.143 dB Peak.
The Frequency Weightings are supplied as:
RMS Detector: A or C, Peak Detector: C or L (Linear).
The Time Weightings can be taken as: Fast, Slow and Impulse (RMS detector).

Table-I Summary of Default Setups

Setup	OSHA	MSHA	DOD	ACGIH	METER	SLM
Measurement Range (dB)	70.140	70.140	70.140	70.140	50.120	70.140
Time Weighting	Slow	Slow	Slow	Slow	Fast	Fast
Frequency Weighting	A	A	A	A	A	A
Peak Frequency Weighting	Lin	Lin	Lin	Lin	C	Lin
Exchange Rate	3 and 5	3 and 5	3 and 4	3	3	3
Threshold (dB)	80	80	80	80	N/A	N/A
Criterion Level (dB)	90	90	85	85	N/A	N/A

II. METHOD OF MEASUREMENT

Measurements are taken in an Electrical Machine Laboratory at Asansol Engineering College, Asansol, Burdwan, in India for different Electrical Machines like DC Shunt Motor, Wound Rotor Induction Motor, Squirrel Cage Induction Motor, Single Phase Induction Motor, Synchronous Motor and DC Shunt Generator etc. The microphone of the noise dosimeter, Brüel & Kjær make, is held close to the rotating shaft of the machine approximately at a distance of 10 cm to 15 cm for a period of 6 hours at an interval of 30 minutes (from 9 AM to 6 PM) in winter season. This process is repeated for each of the six machines, and hence the different parameters of noise produced by the electrical machines during runtime are obtained.

III. RESULTS AND DISCUSSION

Table-III shows the exceedance time for different Electrical Machines, and Table-IV represents the data collected from dosimeter for Lower Threshold, Upper Threshold, L_{eq}, L_{AE}, L_{AV}, TWA, 8 hours projected dose, RMS Maximum Level, RMS Minimum Level and Peak Exceedence Level for six electrical machines present in the machines laboratory of Asansol Engineering College, Asansol. The graph of each machine corresponding to each parameter has been shown below from Fig. 1 to Fig. 9.

Table-II Different Type of Electrical Machines With Specification

Sl. No.	NAME OF THE MACHINE	MOTOR SPECIFICATIONS
1	DC Shunt Motor	5 H.P, 220 V,1500 rpm, 23 Amp
2	Wound Rotor Induction Motor	1 H.P, 415 V, 3-Phase, 1450 rpm,1.6 Amp
3	Squirrel Cage Induction Motor	5.5 kW, 415 ± 10 %, 50 Hz, 3-Phase, 1440 rpm
4	Single Phase Induction Motor	1.5 H.P, 220/240 V, 1-Phase, 1425 rpm, 13 Amp, 1.12 kW
5	Synchronous Motor	240 W,120 V,1500 rpm, 2 Amp
6	DC Generator	1 kW, 220 V, 1500 rpm, 4.55 Amp

Table-III Exceedance Time for Different Electrical Machines

Exceedance Time/Type of Machine	70dB-85dB	85dB-90dB	90dB-100dB	100 dB-115 dB	115dB-140dB
DC Shunt Motor	0.00%	100%	0.52%	0.00%	0.00%
Wound Rotor Induction Motor	0.00%	100%	31.73%	0.00%	0.00%
Squirrel Cage Induction Motor	0.00%	100%	5.54%	0.00%	0.00%
Single Phase Induction Motor	13.14%	86.86%	0.00%	0.00%	0.00%
Synchronous Motor	0.00%	100%	0.04%	0.00%	0.00%
DC Generator	0.00%	100%	74.73%	3.34%	0.00%

Table –IV Noise Parameters For Various Electrical Machines

Noise parameters/Type of Electrical Machine	Lower Threshold (dB)	Upper Threshold (dB)	L_{Aeq} (dB)	L_{AE} (dB)	L_{AV} (dB)	TWA (dB)	8 hours projected dose (dB)	RMS Maximum Level (dB)	RMS Minimum Level (dB)	Peak Exceedance Level (dB)
Dc Shunt Motor	81.8	0.00	82.2	111.9	81.8	56.9	31.87	86.0	77.9	104.1
Wound Rotor Induction Motor	84.5	0.00	84.5	113.9	84.5	59.3	46.51	87.0	82.5	104.1
Squirrel Cage Induction Motor	70.6	0.00	78.3	107.7	70.6	85.4	6.82	90.1	70.4	121.3
Single Phase Induction Motor	0	0.00	73.0	88.7	0	0	0.00	76.5	0	0.00
Synchronous Motor	0	0.00	77.1	106.7	0	0	0.04	85.3	74.4	108.8
DC Genetrator	86.4	0.00	86.6	115.9	86.4	61.0	60.74	90.9	79.5	107.5

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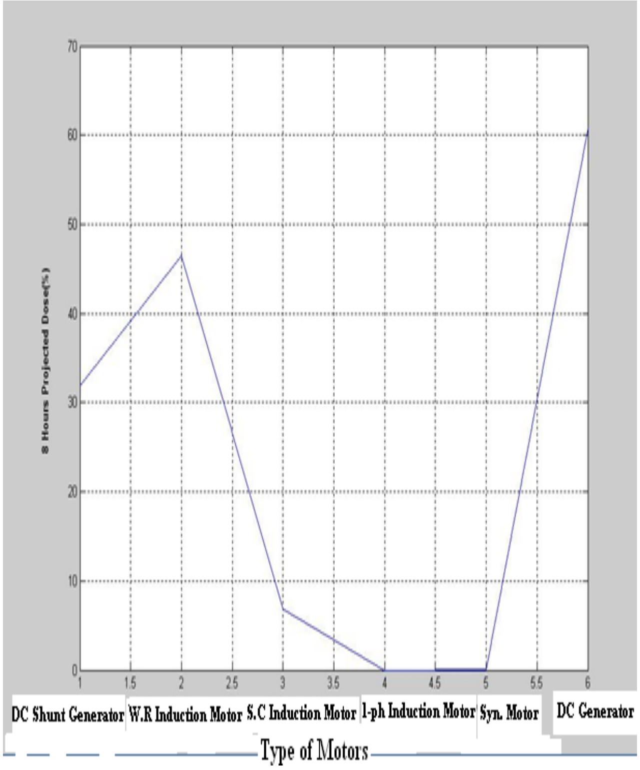

Fig.1. 8 Hours projected dose verses type of machines

Fig. 1 to 9 shows the graphical representation for value of all noise variables like 8 hours projected dose, Equivalent sound level (L_{eq}), Lower Threshold, Peak Exceedence Level, RMS maximum level, RMS minimum level, Sound Exposure level (L_{AE}), Average Sound Level (L_{AV}), Time Weighted Average (TWA) for different electrical machines.

In Fig. 1. 8 hours projected dose verses different types of machines are plotted. 8 hours projected dose of Single Phase Induction Motor and Synchronous Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW and Synchronous Motor is 240 W, but that of DC Generator is 1 kW. As per the power rating the 8 hours projected dose of Single Phase Induction Motor should be greater than that of both DC generator and Synchronous Motor, but it is not so. The reason is that the DC Generator faces some extra losses in the bearings.

By hearing the level of noise sound, one can easily investigate that there is a fault appearing in the electrical machine. Further detailed study of fault locations in the electrical machines are carried out by analysis of the frequency of noise emanating sound and study of noise related parameters like 8 hours projected dose, Equivalent sound level (Leq), Lower Threshold etc. from the respective electrical machine.

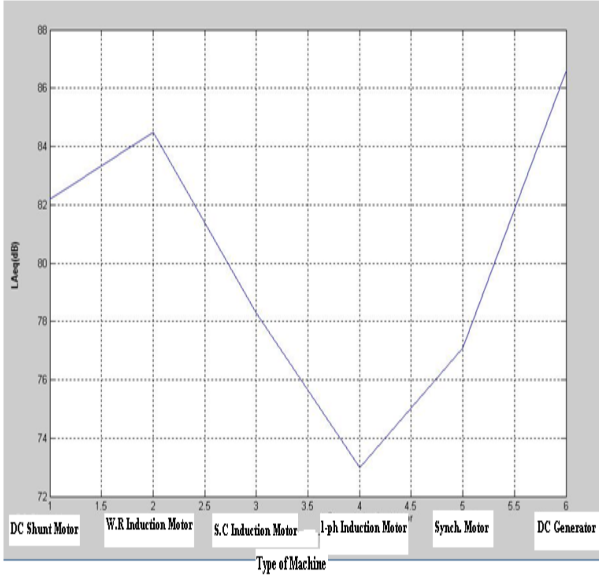

Fig. 2. Equivalent sound level (Leq) vs. different types of machines

In the above Fig. 2. we find the plot of equivalent sound level vs. different types of machines as labeled in the graph. Equivalent sound level of Single Phase Induction Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW, but that of DC Generator is 1 kW. As per the power rating, the Equivalent Sound Level of Single Phase Induction Motor should be greater than that of DC generator, but it is not so. The reason is that the DC Generator encounters some extra frictional losses occurred in the bearings.

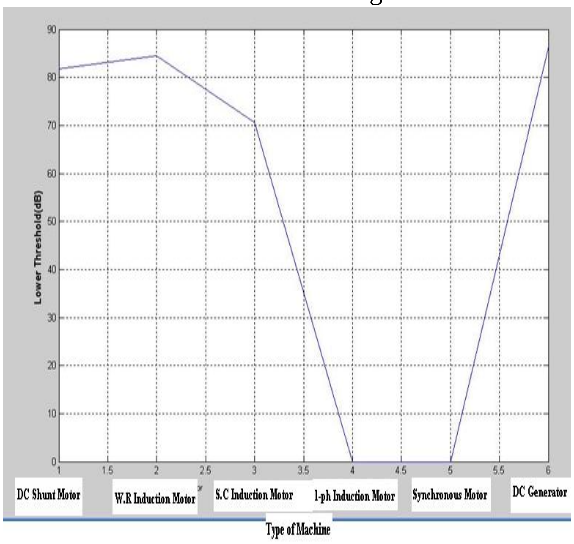

Fig. 3. Lower threshold verses different types of machines

In the above Fig. 3. we plot lower threshold vs. different types of machines as labeled in the graph. Lower Threshold of Single Phase Induction Motor and Synchronous Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW and Synchronous Motor is 240 W, but that of DC Generator is 1 kW.

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As per the power rating the Lower Threshold of Single Phase Induction Motor should be greater than that of both DC generator and Synchronous Motor, but it is not so. The reason is that the DC Generator faces some extra friction in ball bearings.

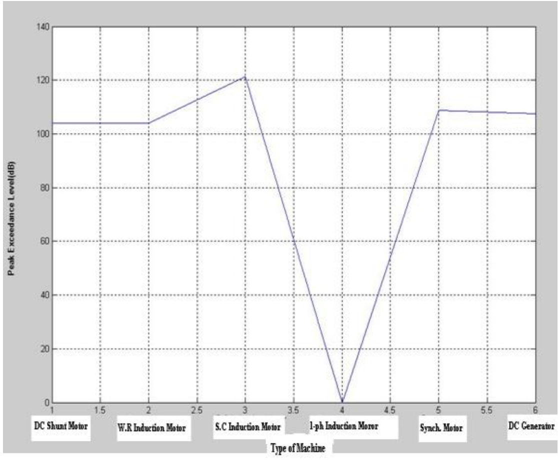

Fig 4- Peak exceedence level verses different types of machines

In the above Fig. 4. we observe the plot of peak exceedence level vs. different types of machines as labeled in the graph. Peak exceedence level of Single Phase Induction Motor is minimum and that of Squirrel Cage Induction Motor is maximum. The power rating of Single Phase Induction Motor is 1.12 kW and that of Squirrel Cage Induction Motor is 5.5 kW. As per the power rating, the peak exceedence level of Squirrel cage Induction Motor is greater than that of Single Phase Induction Motor. Therefore, by careful investigating the level of noise emanating sound from the electrical machines either by its frequency analysis or noise related parameters such as in form of peak exceedence level for Single Phase Induction Motor, Squirrel Cage Induction Motor etc., we can easily locate the faulty parts or region of fault appearing in the respective machine. Thus noise emanating sound parameter like Peak Exceedence level identifies the cause of fault in the electrical machines and immediate repairing or rectifying of the faults appearing in the machines is to be carried out.

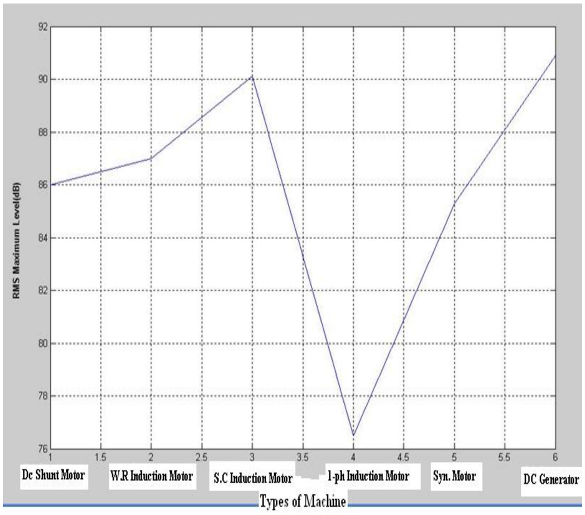

Fig. 5. RMS maximum level verses different types of machines

In the above Fig. 5. we examine the plot of RMS maximum level vs. different types of machines as labeled in the graph. RMS maximum of Single Phase Induction Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW, but that of DC Generator is 1kW. As per the power rating the RMS maximum level of Single Phase Induction Motor should be greater than that of DC generator, but it is not so. The reason is that the DC Generator faces some extra frictional losses in the bearings.

Therefore, the excessive noise exposing sound and its parameters can assure that there is some sorts of fault appear in the respective machine and suitable care has to be taken for isolating the faulty parts or section of the machines immediately.

At the same time this noise exposure above the standard level creates environmental pollution which ultimately causing ill health factor of the workers associated with the faulty electrical machines. To eliminate this environmental pollution due to excessive noise exposure, identified by noise parameter like RMS maximum level etc., preventive and regular maintenance and check up of the electrical machines are to be carried out.

Environmental pollution controlling and good health of the electrical machines are sustained by adopting regular measurement of noise level and its parameters, if any over standard noise such as more than 70~80 decibels sound creating noise exposed from an electrical machine, cause of high noise emitting are studied. At the same time suitable measure has to be taken for controlling environmental pollution in full swing.

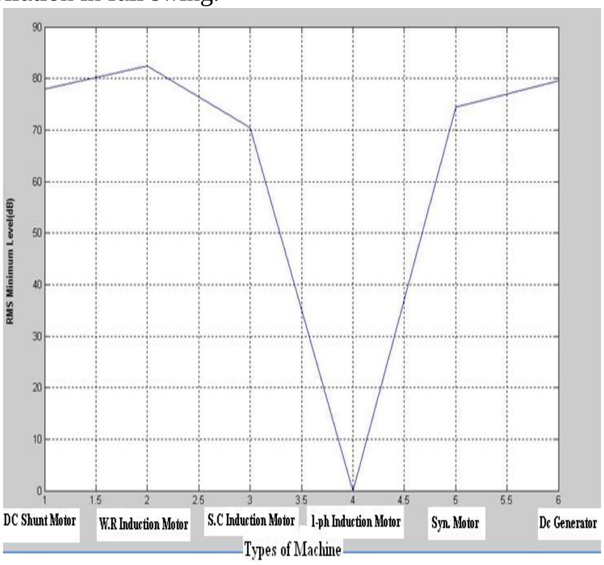

Fig.6. RMS minimum level verses different types of machines

In the above Fig. 6 we see the plot of RMS minimum level vs. different types of machines as labeled in the graph. RMS minimum level of Single Phase Induction Motor is minimum and that of Wound Rotor Induction Motor is maximum.

The power rating of Single Phase Induction Motor is 1.12 kW and that of Wound Rotor Induction Motor is 746 W. As per the power rating, RMS minimum level of Single Phase Induction Motor should be greater than that of Wound Rotor Induction Motor, but it is not so. The reason is that the Wound Rotor Induction Motor again faces some extra losses in the mechanical portion of the motor.

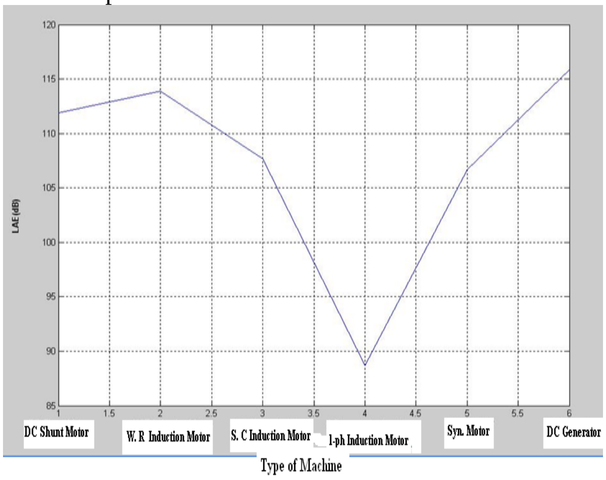

Fig 7. Sound exposure level (LAE) verses different types of machines

In the above Fig. 7. we draw the plot of sound exposure level vs. different types of machines as labeled in the graph. Sound exposure level of Single Phase Induction Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW, but that of DC Generator is1 kW. As per the power rating the sound exposure level of Single Phase Induction Motor should be greater than that of DC generator, but it is not so. The reason is that the DC Generator faces some extra losses in the bearings. Thus noise emanating sound parameter sound exposure level identifies the level of fault and its associated faulty parts existing in the respective electrical machine.

By hearing the unwanted or undesired noise in form of sound, one can easily find the region or area, i.e., the faulty parts of the respective machine. Also investigations are carried out either by analysis of the frequency of noise sound emanating from the machines or noise parameters, faulty section or nature of faults or condition of the electrical machines is identified or predicted.

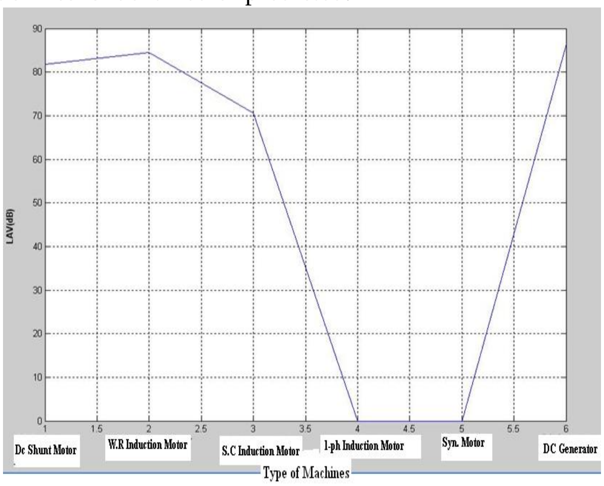

Fig. 8. Average sound level (LAV) verses different types of machines

In the above Fig. 8. we see the plot of average sound level vs. different types of machines as labeled in the graph. Average sound level of Single Phase Induction Motor and Synchronous Motor is minimum and that of DC Generator is maximum. The power rating of Single Phase Induction Motor is 1.12 kW and Synchronous Motor is 240 W, but that of DC Generator is 1 kW. As per the power rating the average sound level of Single Phase Induction Motor should be greater than that of both DC generator and Synchronous Motor, but it is not so. The reason is that the DC Generator faces some extra losses in the bearings.

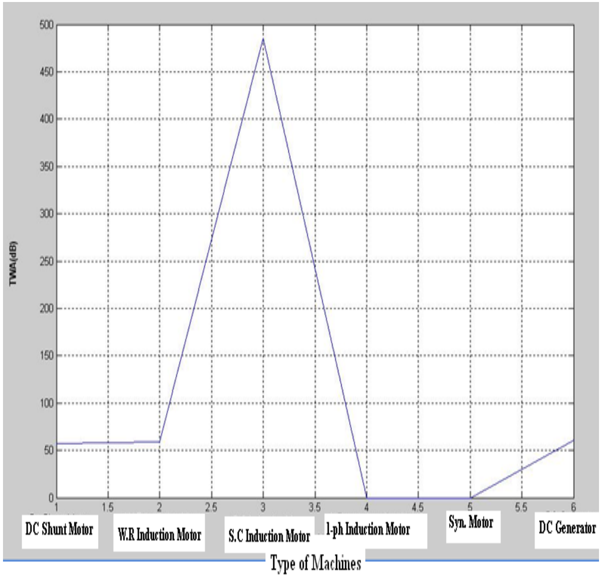

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Fig. 9. Time weighted average (TWA) verses different types of machines

In the above Fig. 9., we check the plot of time weighted average vs. different types of machines as labeled in the graph. Time weighted average of Single Phase Induction Motor and Synchronous Motor is minimum and that of Squirrel Cage Induction Motor is maximum. The power rating of Single Phase Induction Motor is 1.12 kW and Synchronous Motor is 240 W, but that of Squirrel Cage Induction Motor is 5.5 kW. As per the power rating, the time weighted average of Squirrel Cage Induction Motor is greater than that of both Single Phase Induction Motor and Synchronous Motor.

This noise emanating sound from the electrical machines which deliberates Time Weighted Average (TWA) parameter identifies the faulty parts appearing in the respective electrical machine. Moreover constantly exposure to high noise level by the workers in an electrical machines factory or laboratory, environmental pollution in form of hearing loss in manifold, tinnitus, i.e., abnormal sound perceived in the ear, vertigo etc. are arising to the involved workers, and ultimately it causes temporary or permanent deafness. An effective solution to control the excessive sound exposure from the electrical machines has to be achieved. Thus environmental pollution in an electrical machines factory or laboratory can be controlled to adopt regular maintenance of the electrical machines and check up of sound exposure from the electrical machines, it may by noisy in case of faulty machine.

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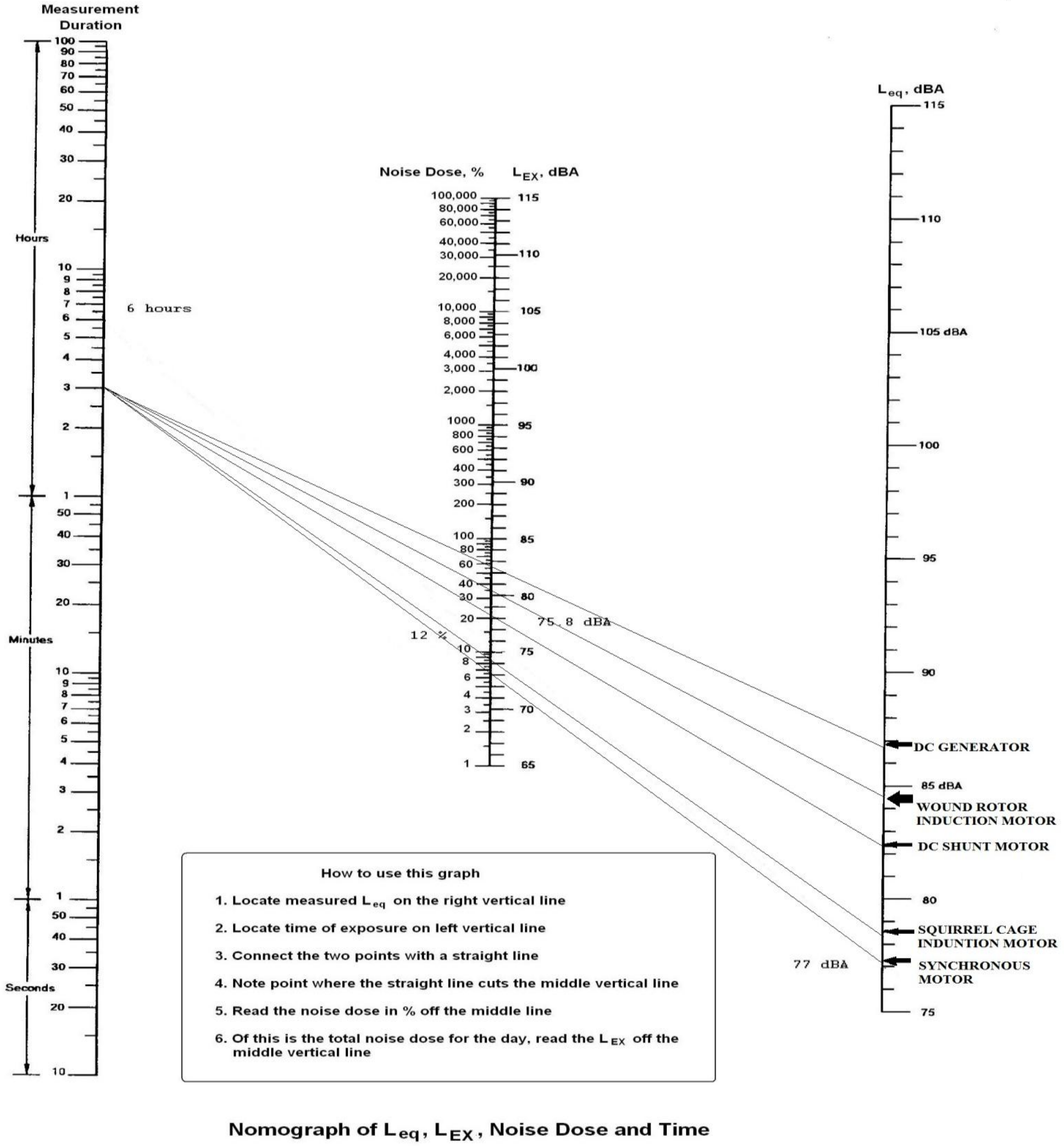

Fig. 10. Nomograph of L_{eq}, L_{EX} (L_{AE}), Noise Dose and time comparison for L_{eq} and L_{AE} as shown in Table IV

IV. NOMOGRAPH TECHNIQUE APPLIED FOR MEASUREMENTS OF L_{EQ}, L_{EX} (L_{AE}), NOISE DOSE

After finding out the value of L_{eq} and L_{AE} from dosimeter, we have used a graphical method called "Nomograph" and plotting the value of L_{eq} and L_{EX} which is equivalent to L_{AE} (Sound Exposure level) in Nomographic scale and the percentage noise dose is found as shown in Fig. 10. The procedure of Nomograph plotting is self explanatory as mentioned in Fig. 10, where L_{EX} is regarded as being the measured L_{eq} with a small correction. Thus it is expressed as $L_{EX} = L_{eq}$ + correction for shift length, where the correction is given by the Table IV and it (L_{EX}) is obtained according to the scale as shown in Fig. 11. Shift time is taken as 6 hours per day for this electrical machine laboratory.

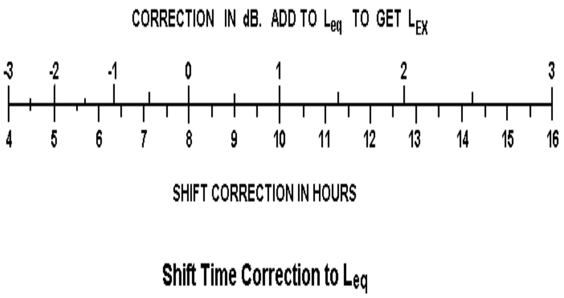

Fig. 11. Shift time correction to Leq

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Table-V Comparison Of Noise Dose Derived From Graphical Method And Dosimeter

Type of Machine	From Nomograph		From Dosimeter	
	Noise Dose (dB)	L_{EX} (Sound exposure level) (dB)	Noise Dose (dB)	L_{AE} (Sound exposure level) (dB)
DC Generator	60%	82.5	60.74%	115.9
Wound Rotor Induction Motor	35%	80.5	46.51%	113.9
DC Shunt Motor	21%	78	31.87%	111.9
Squirrel Cage Induction Motor	9%	74.1	6.82%	107.7
Synchronous Motor	7%	73	0.04%	106.7

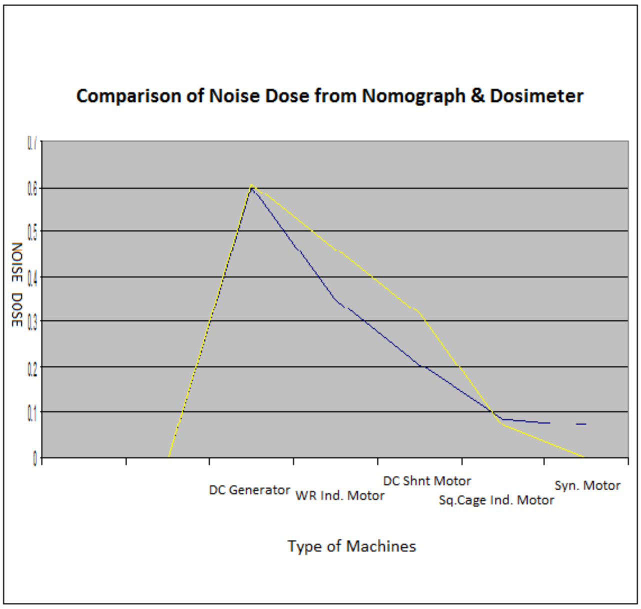

Fig. 12. Percentage Noise Dose obtained from Nomograph and Dosimeter

In Fig. 12, the percentage noise dose obtained from Nomographic technique and Dosimeter is compared and it is clearly shown in the graph.

V. CONCLUSION

The study is based on the measurements of sound as noise emanating from different ac and dc machines, and the results are carefully derived from various electrical machines. The results show that relatively six electrical machines emit high maximum noise levels during respective time allotted period for the specific machine. It is taken 85 dB(A) as maximum value as par guideline and norms of environmental noise-induced annoyance. Thus for smooth running condition and low noise emitting, regular periodic as well as preventive maintenance are to be carried for each and every machine and its accessory parts. The present study is compared the effects of noises emitted from various electrical machines applied with the same equivalent noise levels. It is easily pointed out the faulty section or parts of the machines by its noise emitting characteristics, i.e., by analysis either the frequency of noise emanating sound from the electrical machines or noise related parameters or both, the condition and faulty parts (if any) of the electrical machines are identified. In doing the laboratory study on response to noise, the type of activity based annoyance by the electrical machines noises are investigated and suitable measure is to be taken to prevent noise related environmental pollution causing by the electrical machines.

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