International Journal of Applied Engineering Research ISSN 0973-4562 Volume 18, Number 4 (2023) pp. 363-367
© Research India Publications.

Evaluation of Radio Interference and Audible Noise Produced by Transmission Lines

J. Morales and E. Orduña
Professor, Institute of Electric Energy, National University of San Juan
San Juan, Argentina

D. Quezada
Empresa Eléctrica de Azogues, Azogues, Ecuador

J. P. Cevallos
CEVARM CIA Electrical Construction Company. LTDA, Loja, Ecuador

Abstract

In operation normal conditions, Transmission Lines can generate electromagnetic emissions in various frequency ranges due to the phenomenon known as corona effect. Thus, phenomena such as Radio Interference and Audible Noise can be present, which can interfere as the normal operation of nearby electromagnetic devices as to causing auditory impacts on the environment. In this context, this paper presents the evaluation of both Radio Interference and Audible Noise corresponding to a 132 kV double circuit Transmission Line. The values are determined from the center of the conductors' location up to a length of 50 meters, in steps of 5 meters respectively.

Keywords:- Audible noise, radio interference, limits value.

INTRODUCTION

Electricity demand has experienced notable increases in recent years, driving the integration of various generation plants and transmission systems. This effort seeks to improve stability and ensure an efficient electricity supply in anticipation of a probable increase in demand in the coming years, being essential to have transmission systems capable of evacuating the generated energy. High voltage Transmission Lines (LT) play a crucial role in transporting energy from generating plants to consumption centers, maintaining optimal operating conditions at a nominal frequency of 50/60 Hz. However, under normal conditions, LTs can generate electromagnetic emissions in various frequency ranges due to the phenomenon known as the corona effect. These emissions can interfere with the normal operation of nearby electromagnetic devices, in addition to causing auditory impacts to the environment. Addressing these challenges requires careful attention to the planning and design of TLs, implementing technologies and practices that mitigate the adverse effects of the Corona Effect (CE) [1].

The corona effect is produced when the potential of the conductor of a TL exceeds the dielectric strength of the surrounding air. This phenomenon tends to manifest itself in points distributed randomly along the conductors of the TL. The effects derived from the corona effect can encompass various outcomes, including Audible Noise (AR) and Radio Interference (RI) [1-2]. Based on the above, this work presents the evaluation of RI and RA generated by a 132 kV double-circuit LAT with guard wire and considering an angular suspension structure. These calculated values are compared with international regulations, both RI and RA, respectively.

THEORETICAL BASIS

The corona discharge in LTs manifests itself as partial electric discharges in the air around the conductors, generated by a high electric field that induces the ionization of neutral molecules, giving rise to the CE. According to the IEEE, this phenomenon is defined as a luminous discharge caused by the ionization of the air around an electrode due to a voltage gradient that exceeds a critical value. Characteristics of the corona effect include pulses of current and emission of electromagnetic waves audible, such as humming, and sometimes visible as a violet glow at night. Among the phenomena generated by the corona effect are:

Radio interference RI

When a conductor of a LAT experiences a voltage increase, its surface potential gradient can exceed the breakdown of air, inducing its ionization. RI in LT, generally caused by the CE on conductors, is characterized by a frequency spectrum that does not exceed a few MHz. The magnitude of RI depends on factors such as the electric field on the surface of the conductors and the distance between the disturbance source and the measurement point. The estimation of the order of magnitude of radio interference (in dB over 1μV/m) is achieved through numerical evaluation and empirical formulas, calculating the maximum potential gradient over the conductors [1].

Audible Noise AN

This phenomenon, mainly noticeable in adverse weather conditions, is characterized by a bandwidth that covers frequencies close to 20 kHz [1]. AN manifests itself as a persistent ringing sound, with sporadic popping. This noise is considered a direct consequence of the CE in TL, defined as a luminous discharge caused by the ionization of air due to a voltage gradient that exceeds a critical value. LTs can generate audible noise associated with the CE, with a broadband spectrum and pure sounds [3].

AN and RI calculation methodology

In order to evaluate the values of RI and AN, different parameters that are necessary will initially be determined. These initial parameters include performing the calculations mentioned below [1]-[4]:

Determination of the surface gradient of the conductors*:* Using the potential coefficient method, the charges of the conductor system are determined, through the application of image theory, replacing the ground plane with the image of the conductor with respect to the plane. Based on this principle, the electric field, and the coefficients of the conductor's own potential as well as the mutual potential between conductors are determined.

Determination of the LAT capacitance matrix: The determination of the capacitance matrix of line **C** is carried out, which is based on the principle of the known potential coefficients of the own and mutual conductors. Subsequently, the q_i charges of each conductor are determined, and the average surface gradient over each conductor can be determined.

Determination of RI: At this point, based on data extracted over the years in different LAT configurations, CIGRE and the IEEE developed an empirical formula relating the most important lines and atmospheric conditions. Based on the above, the RI level at 20 m distance from the phase with the highest electric field is calculated as follows:

$$RI_i(dB) = 3.5gm + 12r - 33log\left(\frac{D_i}{20}\right) - 30 \qquad (1)$$

Where:

r is the radius of the subconductor at equal voltage, in cm.

g_m is the maximum surface gradient of conductor *i*, in KV/cm.

D_i is the distance from conductor *i* to the RI measurement point, in m.

Determination of AN: Finally, the AN calculation method, proposed by the FGH of Germany, can be applied to any transmission line. The AN_i Audible Noise level for phase *i* is given by:

$$AN_i = 2E_i + 45\,log(d) + 18log(N) - 0.3 - 10log(R_i) \qquad (2)$$

where:

E_i is the electric field at the surface of the conductor in kV/cm

d is the conductor diameter in cm

N is the number of conductors per phase

R_i is the distance from the conductor to the calculation point in m.

The AN for a TL is:

$$AN = 10log \sum_{i=1}^{n} 10^{\left(\frac{RA_i}{10}\right)} \qquad (3)$$

where:

n is the total number of phases.

RI and AN regulations

According to the US Environmental Protection Agency (EPA) the day-night average sound level of AN in residential areas should be limited to 55 dB A outdoors and 45 dB A indoors. Therefore, the reference levels used for the present study are based on international regulations and national references applied for this type of studies, as presented below [1]:

- Less than 52.5 dBA nobothers.
- Between 52.5 and 59 dBA,bothers a little
- More than 59 dBAbothers

On the other hand, Radio Interference (RI) Canadian Standards Association (CSA) has developed a standard [5], for interference from high voltage ac power systems. This standard applies to radio interference in the frequency range of 0.15 MHz- 30 MHz generated by ac power lines. The standard specifies that the fair-weather interference field strength, from the outermost conductor of the power line shall not exceed 49 (dB µV/m) for 70-200 kV lines at frequency of 0.5 MHz.

ELECTRICAL POWER SYSTEM SIMULATED

Figure 1 shows the conductor configuration used in this paper. With respect to the characteristics of the TL and its conductors, it is made up of conductors that allow an admissible current of approximately 600 A per phase to flow. The spans between transmission towers are 220m, number of circuits 2 and one earth wire. Table 1 presents the characteristics of the conductors.

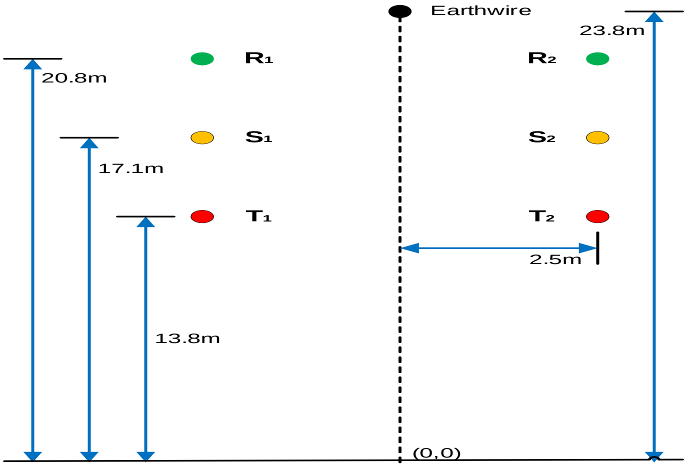

Figure 1 Conductor configuration

Table 1 Characteristics of the phase conductor and guard.

Denomination	Phase wire characteristics	Earth wire Features
Section	353.7 mm2	114 mm2
External diameter	24.5mm	13.8mm
Weight with fat	1.24 kg/m	596kg/km
Breaking load	10707kg	8583kg
Composition	26*3.86+7*3	

A. Study cases

To quantify and determine the most critical case about the combination of phases, it is important to indicate that in the case of the RI and AN study, the different combinations of phases were analyzed to determine all possible levels that may be presented in the TL. In this context, nine possible study cases are analyzed as presented in Table 2. Additionally, the RI and AN values are determined at different distances from the conductor location. In this sense, distances from -50m to 50 meters with steps of 5 m are considered.

Table 2 Case studies.

Case study	Phase arrangement
1	Maximum voltage in the upper phases of both circuits
2	Maximum voltage in the upper phase of the first circuit and maximum voltage in the central phase of the second circuit
3	Maximum voltage in the upper phase of the first circuit and maximum voltage in the lower phase of the second circuit
4	Maximum voltage in the central phase of the first circuit and maximum voltage in the upper phase of the first circuit
5	Maximum voltage in the central phases of both circuits
6	Maximum voltage in the central phase of the first circuit and maximum voltage in the lower phase of the second circuit
7	Maximum voltage in the lower phase of the first circuit and maximum voltage in the upper phase of the second circuit
8	Maximum voltage in the lower phase of the first circuit and maximum voltage in the central phase of the second circuit
9	Maximum voltage in the lower phases of both circuits

RESULTS

Based on the above said, numerical determination using internationally recognized empirical equations allows the levels of RI and AN to be determined. Table 3 presents a summary of the maximum values of RI and AN determined at 20m, considering the different voltage configurations (See Table 2).

Based on Table 3 and Figure 2 and 3, it can be seen that the maximum and minimum value of RI is 24.24 (dB/ 1 µV/m) and 21.84 (dB/ 1 µV/m), respectively. It can be noted that the maximum values are presented in study cases 2 and 7. On the other hand, the minimum values are presented in study cases 5 and 9. However, it can be see that the RI values are lower than the tolerable limit value which is 49 (dB/ 1 µV/m).

Regarding the AN, it can be seen that the maximum and minimum value are 34.06 dB(A) and 32.71 dB(A), respectively. Where the maximum value is presented in the case study 3 and the minimum value is presented in the cases 1, 7 and 9. However, in the same way the simulation shows that the AN values generated by CE do not exceed the established limit of 52.5 dB(A), from 20 meters from the conductor location.

Table 3 Maximum values of RI and AN at 20 meters away

Case study	Radio interference [dB/ 1 µV/m] At 1.0 MHz	Acoustic noise dB(A)
1	21.8469	32,712
2	24.24	33.9
3	24.2	34,062
4	23.83	33,371
5	21.84	32,712
6	22.29	33,359
7	24.24	33.9
8	22.29	33,359
9	21.84	32,712

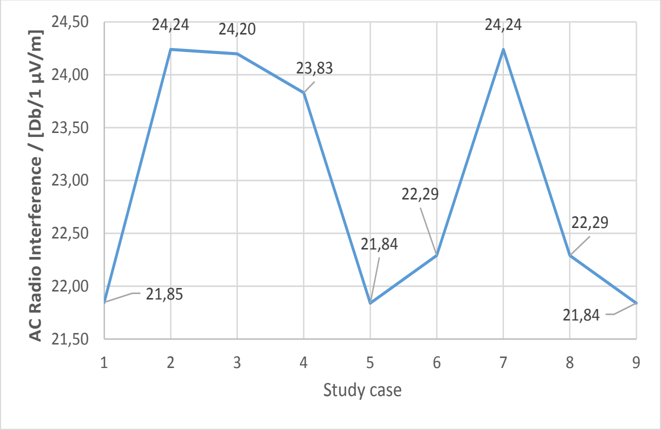

Figure 2: Radio interference levels at 20 m

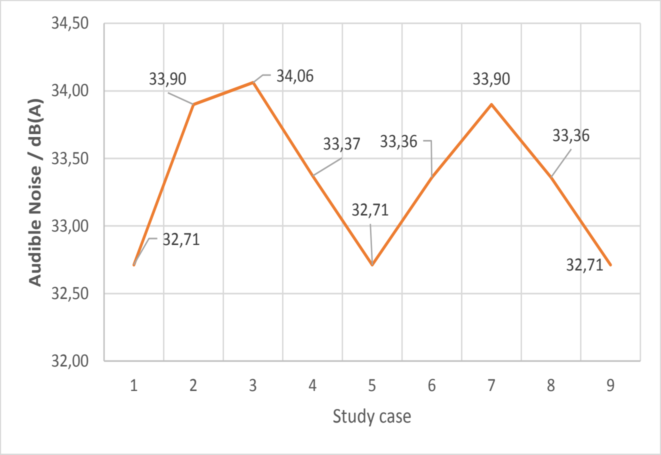

Figure 3: Audible noise levels at 20 m

Additionally, it should be noted that the RI and AN values are simulated for different distances from the location of the conductors. The results for each of the distances are presented in Table 4.

Case study	Radio interference [dB/ 1 µV/m] At 1.0 MHz																				
	Distance																				
	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50
1	8.71	10.22	11.91	13.83	16.03	18.64	21.85	25.97	31.78	41.71	295.78	41.71	31.78	25.97	21.85	18.64	16.03	13.83	11.91	10.22	8.71
2	11,10	12.61	14.30	16.22	18.43	21.04	24.24	28.36	34.17	44.10	298.17	44.10	34.17	28.36	24.24	21.04	18.43	16.22	14.30	12.61	11,10
3	11.07	12.58	14.27	16,19	18.39	21.00	24.20	28.32	34.13	44.07	298.13	44.07	34.13	28.32	24.20	21.00	18.39	16,19	14.27	12.58	11.07
4	10.70	12.21	13.89	15.81	18.02	20.63	23.83	27.95	33.76	43.70	297.76	43.70	33.76	27.95	23.83	20.63	18.02	15.81	13.89	12.21	10.70
5	8.71	10.22	11.91	13.82	16.06	18.64	21.84	25.96	31.78	41.71	295.57	41.71	31.78	25.96	21.84	18.64	16.06	13.82	11.91	10.22	8.71
6	9.16	10.67	12.36	14.27	16.48	19.09	22.29	26.41	32.22	42.16	296.22	42.16	32.22	26.41	22.29	19.09	16.48	14.27	12.36	10.67	9.16
7	11,10	12.61	14.30	16.22	18.43	21.04	24.24	28.36	34.17	44.10	298.17	44.10	34.17	28.36	24.24	21.04	18.43	16.22	14.30	12.61	11,10
8	9.16	10.67	12.36	14.27	16.48	19.10	22.29	26.41	32.22	42.16	296.22	42.16	32.22	26.41	22.29	19.10	16.48	14.27	12.36	10.67	9.16
9	8.72	10.22	11.91	13.82	16.04	18.64	21.84	25.97	31.78	41.71	295.78	41.71	31.78	25.97	21.84	18.64	16.04	13.82	11.91	10.22	8.72

Table 3 Value of Radio Interference

Case study	**Audible noise dB(A)**																				
	Distance																				
	-50	**-45**	**-40**	**-35**	**-30**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
1	28.73	29.19	29.70	30.28	30.95	31.74	32.71	33.96	35.72	38.73	115.72	38.73	35.72	33.96	32.71	31.74	30.95	30.28	29.70	29.19	28.73
2	30.00	30.48	30.99	31.56	32.23	33.03	33.90	35.25	37.00	40.00	117.01	40.00	37.00	35.25	33.90	33.03	32.23	31.56	30.99	30.48	30.00
3	30.08	30.54	31.05	31.63	32.30	33.09	34.06	35.31	37.07	40.08	117.07	40.08	37.07	35.31	34.06	33.09	32.30	31.63	31.05	30.54	30.08
4	29.39	29.85	30.36	30.94	32.61	32.40	33.37	34.62	36.38	39.39	116.38	39.39	36.38	34.62	33.37	32.40	32.61	30.94	30.36	29.85	29.39
5	28.73	29.19	29.70	30.28	30.95	31.74	32.71	33.96	35.72	38.73	115.72	38.73	35.72	33.96	32.71	31.74	30.95	30.28	29.70	29.19	28.3
6	29.38	29.84	30.35	30.93	31.60	32.39	33.36	34.61	36.37	39.38	116.37	39.38	36.37	34.61	33.36	32.39	31.60	30.93	30.35	29.84	29.38
7	30.02	30.48	30.99	31.57	32.24	33.03	33.90	35.25	37.00	40.02	117.01	40.02	37.00	35.25	33.90	33.03	32.24	31.57	30.99	30.48	30.02
8	29.38	29.84	30.35	30.92	31.60	32.39	33.36	34.60	36.37	39.38	116.37	39.38	36.37	34.60	33.36	32.39	31.60	30.92	30.35	29.84	29.38
9	28.73	29.19	29.70	30.28	30.95	31.74	32.71	33.96	35.72	38.73	115.72	38.73	35.72	33.96	32.71	31.74	30.95	30.28	29.70	29.19	28.73

Table 4 Value of Audible Noise

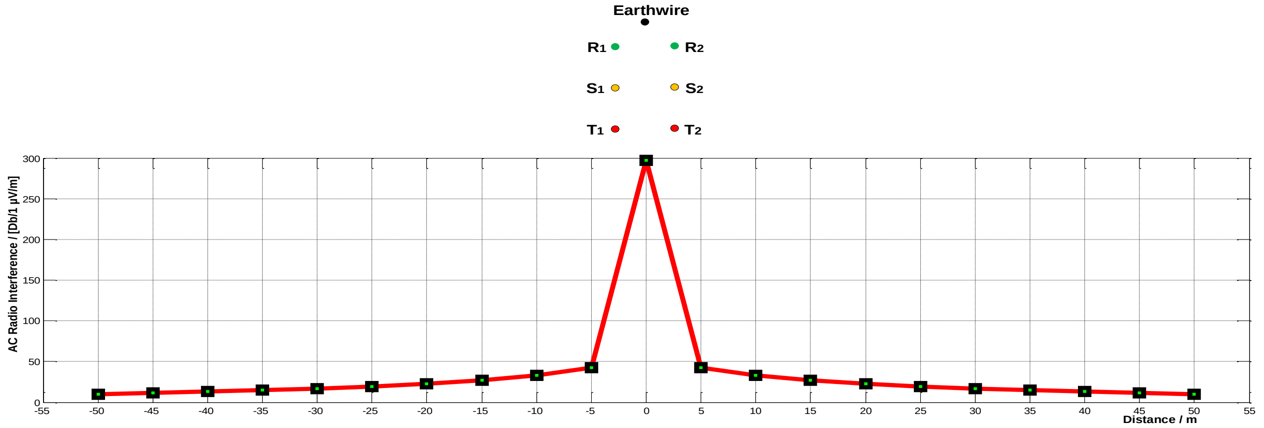

Figure 3 Average value of Radio Interference

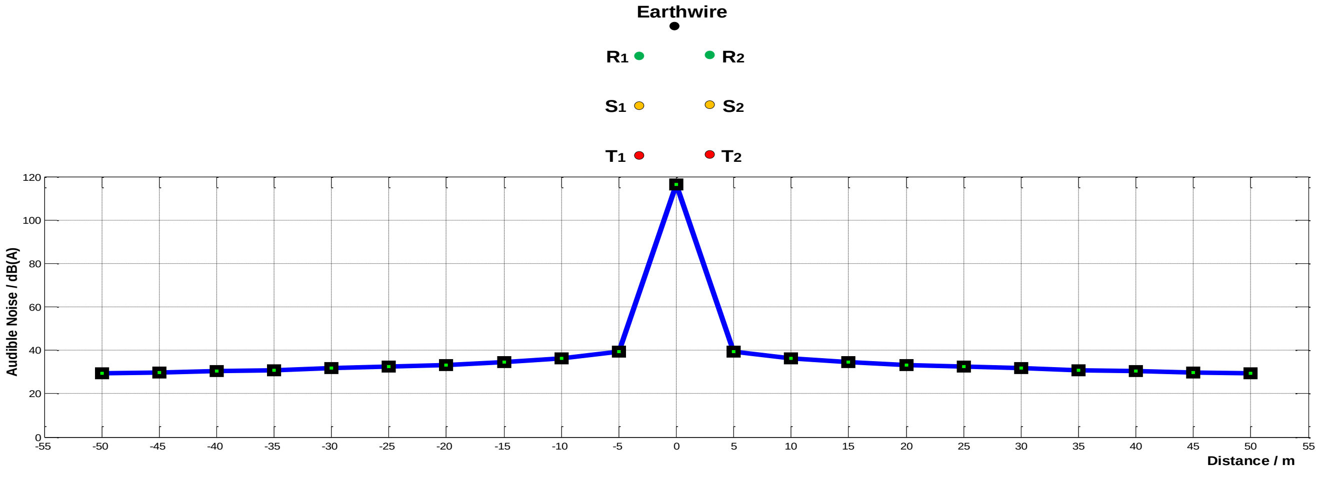

Figure 4 Average Audible Noise Value

Based on Table 4, it can be seen that the highest values of RI and AN occur at a distance approximately zero m corresponding to the distance from the center of the location of the conductors to the calculation point. It can be seen that regardless of the case study analyzed, the RI value in the center point of the conductors is approximately 295 (dB/1 μV/m). On the other hand, it can also be seen that, at a distance of 5 m from the location of the conductors, the RI value is approximately 42 (dB/1 μV/m), which means a reduction of approximately 85.76%. As the distance from the center of the conductors increases, the RI value decreases considerably. It can be seen that practicing at a distance of 5m, the RI values do not exceed the limit value of 49 (dB/ 1 μV/m).

With respect to AN, it can be seen that regardless of the case study analyzed, the value of AN in the center point of the conductors is approximately 116 dB(A). On the other hand, it can also be seen that, at a distance of 5 m from the location of the conductors, the AN value is approximately 39 dB(A), which means a reduction of approximately 66.38%. In addition, as the distance from the center of the conductors increases, the AN value decreases considerably. It can be seen that at a distance of 5m, the AN values do not exceed the limit value of 52.5 dB(A). Based on the above said, Fig. 4 shows the average value of RI and AN corresponding to the Table 4.

CONCLUSIONS

As a result of the determination of the RI and AN levels produced by TL, the following conclusions are presented:

Both the maximum and minimum value of RI determined at 20 meters from the phase wire with the highest electric field value, considering all possible study cases, are 24.24 (dB/1 μV/m) and 21.84 (dB/1 μV/m) , which are lower than the value of 49 (dB/ 1 μV/m), recommended as a tolerable limit value for the 132kV TL under study.

Similarly, with respect to the AN value, both the maximum and minimum values determined in the present study are 34.06 dB(A) and 32.71 dB(A). However, both values are also lower than the value recommended as a tolerable limit value for the TL of 132 kV (52.5dB(A)).

Furthermore, based on the values of both RI and AN at different distances from the location of the conductor, it can be observed that the largest values of RI and AN occur in the center of the conductors. However, as the distance reaches 5m, the RI and AN values decrease considerably, which are lower than the values recommended by the corresponding regulations for a distance of 20m.

ACKNOWLEDGMENT

The authors gratefully acknowledge: the Instituto de Energía Eléctrica at Universidad Nacional de San Juan, and Constructora Eléctrica CEVARM CIA. LTDA, for the assistance and financial support.

REFERENCES

[1] Electric Power Research Institute. Transmission Line Reference Book, 345 kV and Above / Second Edition Revised. California. 1982

[2] Peek, F. Dielectric Phenomena in High Voltage Engineering. McGraw-Hill. New York. 1929.

[3] IEEE Std. 656. “IEEE standard procedures for measurement of audible noise from overhead transmission lines.” 1992

[4] N. Morales, "Corona phenomenon in transmission lines and its effects." Publication T(P)/9, Department of Electrical Engineering. November 1986.

[5] CSA C108.3.1-M84, Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems 0.15 - 30 MHz