IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Electromagnetic field impact on 150 kV Raha-Baubau transmission line

To cite this article: Yusran 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **235** 012107

IOP Conf. Series: Earth and Environmental Science 235 (2019) 012107 doi:10.1088/1755-1315/235/1/012107

Electromagnetic field impact on 150 kV Raha-Baubau transmission line

Yusran

Department of Electrical Engineering, Hasanuddin University, Makassar, Indonesia

E-mail: *yusran@unhas.ac.id, yusranibnu@yahoo.com*

Abstract. The construction of 150 kV transmission line in Southeast Sulawesi is intended to establish interconnection with South Sulawesi system. The one of the transmission lines will be built 150 kV Raha-Baubau transmission line. One of the main potential impacts of the transmission line is electromagnetic field radiation. The value of electromagnetic field generating by transmission line can be conducted by calculation and simulation as studied in this research. This research was used shadow conductor approach method. The calculation and simulation results were showed that the largest electric field value occurring at two coordinates points (-7,2) and (7,2) with 0.366778 kV/m. The largest magnetic field was happening at coordinate (0,2) with 3.186838 A/m or 0.004 mT. Both electric and magnetic field radiation were still below the specified standard value, 5 kV/m for the electric field and 0.1 mT for the magnetic field.

1. Introduction

The electrical power systems are divided into three main parts namely; generation, transmission and distribution [1][2]. Power generation can be either centralized generation or distributed generation [3]. Centralized generation is generally a large-scale power plant while distributed generation in the form of small-scale power plants [4]. Transmission lines are generally required to evacuate electrical power from centralized generation. On the other side, the distributed generation system is directly connected to the distribution system.

The 150 kV transmission line constructions in Southeast Sulawesi Province are mostly the development of interconnection Southeast Sulawesi system with South Sulawesi system. The interconnection extends from Malili, Lasusua, Kolaka, Unaaha to Kendari. The 150 kV transmission line will be developed to serve the district capitals that have been an isolated system. The nickel minerals processing industry (smelter) requires large-scale electric power. The electricity demand for the smelter will be met from several large-scale hydropower in the area, around the border of South Sulawesi, Central Sulawesi and West Sulawesi [5].

Another construction is an interconnection of Raha system in Muna Island with Baubau system in Buton Island through 150 kV Raha-Baubau transmission line. The transmission line is planned to connect Raha Substation (new) and Baubau Substation (new). The transmission line will pass through four regencies in Southeast Sulawesi Province: Muna District, West Muna District, Central Buton District and Baubau District. The general data of the transmission line as follows:

- Length: 99405.34 m or ± 99.4 km
- Number of the tower (TIP) : 278 pieces

- Type of conductor : ACSR 240
- Circuit configuration : double circuit

The transmission line is very important to evacuate electrical power. It will correlate with economic development and social welfare. On the other side, the transmission line also has potential impacts, especially health impact on the community. One of the things that should get special attention is the determination of vertical minimum distance design from the conductor to the object under it. The minimum clearance related with the magnitude of electromagnetic field exposure occurring at operation phase. The magnitude must be compared with existing standard. This study was focused on the calculation and simulation of electromagnetic field arising based on available design.

The transmission line operation will generate an electromagnetic field in the form of electric field expressed in kV/m and magnetic field expressed in A/m or Tesla [6][7]. The criteria used in the exposure limits are induced currents density in the body. Since the induced currents in the body cannot easily measure directly, the exposure limits are derived from the criterion values of the induced currents in the body in the form of electric field strength (E) and magnetic flux density (B).

2. The earth influence on the electric and magnetic field of transmission line

By assuming the earth to be a perfect conductor in the infinite horizontal plane, it is understandable that the electric field generated by the charged line over the earth will not be as if the earth's equipotential surface does not exist [8]. This leads to the calculation of the electric field and the magnetic field due to the conductor transmission line located above the earth's surface that will have negatively charged shadows beneath the earth's surface as shown in figure 1 below.

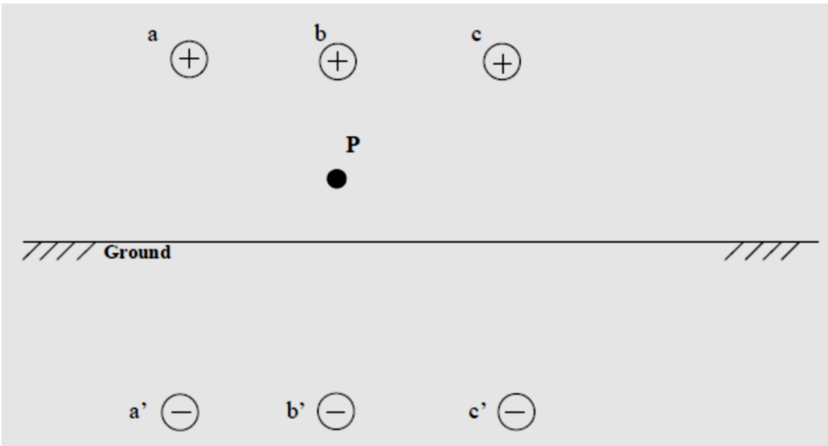

Figure 1. Phase conductor a, b and c and their respective shadows

The conductors of a, b and c have Va, Vb, Vc voltage and Ia, Ib and Ic current. It will have a shadow beneath the surface of the earth ie a', b' and c' which have equivalent voltage and current to its mirrored but reflective sign. Thus the respective shadow line will have -Va, -Vb, -Vc voltage and -Ia, -Ib and -Ic current.

Because of the presence of these shadow conductors, the total electric field strength at point P is the sum of electric field superposition due to each conductor and its shadow. If the electric field due to the conductor a, b and c and its shadow respectively are Ea, Eb, Ec, Ea', Eb' and Ec', then the total electric field at point P (Ep) is:

$$Ep = Ea + Eb + Ec + Ea' + Eb' + Ec' \quad V/m \tag{1}$$

Similarly with the magnetic field due to the transmission line, the presence of shadow conductor is thought to result in the flow of electric currents in the shadow conductor. If the magnetic field due to the conductor and its shadow respectively are Ha, Hb, Hc, Ha', Hb' and Hc', then the total magnetic field at point P (Hp) is:

$$Hp = Ha + Hb + Hc + Ha' + Hb' + Hc' \quad A/m \tag{2}$$

Then the total magnetic field density at point P (Bp) is:

$$Bp = \mu_0 . Hp \quad Tesla \tag{3}$$

3. Maxwell potential and induction coefficients

Maxwell was formulated a relationship between charge and potential, applicable including to the line conductor. The system consists of n conductors, where n = 1, 2, 3 ... n, the equation can be written as a function of the charges Q1, Q2, Q3 ... Qn.

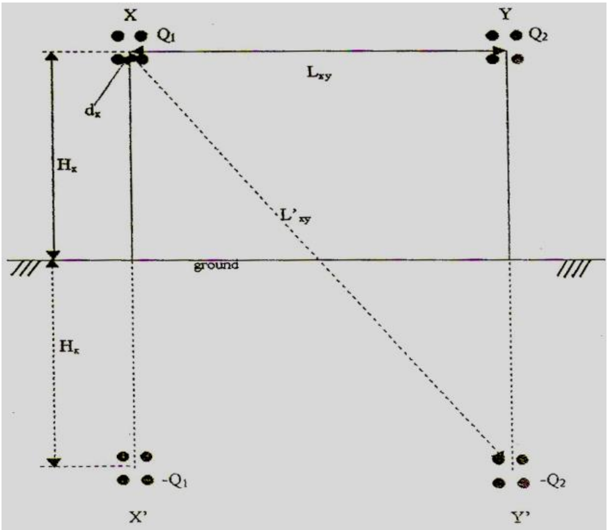

Figure 2. The conductors and its shadow

From figure2, the voltage equation of each conductor can be written:

$$V_1 = \frac{Q_1}{2\pi\varepsilon}\ln\frac{2H_x}{d_x} + \frac{Q_2}{2\pi.\varepsilon}\ln\frac{L'_{12}}{L_{12}} + ... + \frac{Q_n}{2\pi\varepsilon}\ln\frac{L'_{1n}}{L_{1n}}$$

$$V_2 = \frac{Q_1}{2\pi\varepsilon}\ln\frac{L'_{21}}{L_{21}} + \frac{Q_2}{2\pi.\varepsilon}\ln\frac{2H_X}{d_x} + ... + \frac{Q_n}{2\pi\varepsilon}\ln\frac{L'_{2n}}{L_{2n}}$$

$$V_n = \frac{Q_1}{2\pi\varepsilon}\ln\frac{L'_{a1}}{L_{a1}} + \frac{Q_2}{2\pi.\varepsilon}\ln\frac{L'_{a2}}{L_{a2}} + ... + \frac{Q_n}{2\pi\varepsilon}\ln\frac{L'_{nn}}{L_{nn}} \tag{4}$$

where:

$V_{1,2}\ldots,V_n$= voltage of each conductor (Volt)
$Q_{1,2}...,V_n$ = charge of each conductor (Coulomb)
$H_n,...,H_n$ = height of conductor from ground level (meter)
$d_x,...,d_n$ = the equivalent diameter of the conductor (meter)
L_{xy} = distance between conductor X and conductor Y (meter)
L'_{xy} = distance between the conductor X and the shadow of the conductor Y (meter)

The equation (4), can be written as follows:

$V_1 = P_{11}Q_1 + P_{12}Q_2 + ... + P_{1n}Q_n$
$V_2 = P_{21}Q_1 + P_{22}Q_2 + ... + P_{2n}Q_n$

$V_n = P_{n1}Q_1 + P_{22}\,Q_2 + \ldots\ldots\ldots\ldots + P_{nn}Q_n$(5)

The equation (5) can be written in matrix form as:

$$[\,V\,] = [\,P\,]\,[\,Q\,] \tag{6}$$

or

$$[\,Q\,] = [\,P\,]^{-1}\,[\,V\,] \tag{7}$$

The voltage and charges can be represented as complex number, thus the equation (7) can be written as:

$$[\,Q\,] = [\,Q_r\,] + j\,[\,Q_i\,] = [\,P\,]^{-1}\,\{\,[\,V_r\,] + j\,[\,V_i\,]\,\} \tag{8}$$

Where P is a constant depending on distance between the conductor and the permittivity. P referred to Maxwell's potential coefficients with magnitude of the elements are

$$P_{xx} = \frac{1}{2\pi\varepsilon}\ln\left[\frac{2H_x}{r_x}\right] \tag{9}$$

$$P_{xx} = \frac{1}{2\pi\varepsilon}\ln\left[\frac{L'_{xy}}{L_{xy}}\right] \tag{10}$$

Where:

H_x = high conductor x above ground
r_x = conductor radius,
L_{xy} = the distance between the conductor x and the conductor y
$L_{xy'}$ = the distance between the conductor x and the shadow of the y conductor
$\varepsilon = \varepsilon_o$ = permittivity of free space (8,854 x 10-12 F/m)

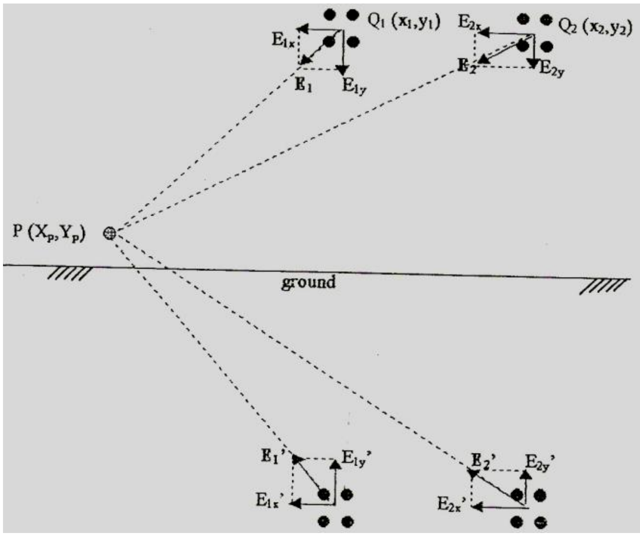

Figure 3. The field strength at point P generating by two conductor

In figure 3 above, the electric field strength at point P caused by conductor 1 is:

$$\overline{E_{1x}} = \frac{Q_1}{2\pi.\varepsilon}\left\{\frac{(X_1 - X_p)}{(X_1 - X_p)^2 + (Y_1 - Y_p)^2} - \frac{(X_1 - X_p)}{(X_1 - X_p)^2 + (Y_1 + Y_p)^2}\right\} \tag{11}$$

$$\overline{E_{1y}} = \frac{Q_1}{2\pi.\varepsilon}\left\{\frac{(Y_1 - Y_p)}{(X_1 - X_p)^2 + (Y_1 - Y_p)^2} - \frac{(Y_1 + Y_p)}{(X_1 - X_p)^2 + (Y_1 + Y_p)^2}\right\} \tag{12}$$

Where:

$\overline{E_{1x}}$ = The strength of the electric field due to conductor 1 with X axis direction

$\overline{E_{1y}}$ = The strength of the electric field due to conductor 1 with Y axis direction

By combining equations (11) and (12), the value of the electric field is obtained at point P due to conductor 1 and its shadow:

$$\overline{E_1} + \overline{E_1^{'}} = \overline{E_{1x}} + \overline{E_{1y}}$$

$$E_n = \frac{Q_n}{2\pi.\varepsilon}\left\{\frac{(X_1 - X_p) + (Y_1 - Y_p)}{(X_1 - X_p)^2 + (Y_1 - Y_p)^2}\right\} - \frac{Q_n}{2\pi.\varepsilon}\left\{\frac{(X_1 - X_p) + (Y_1 + Y_p)}{(X_1 - X_p)^2 + (Y_1 + Y_p)^2}\right\}$$

$$\overline{E_p} = \overline{E}_1 + \overline{E_1^{'}} + \overline{E_2} + \overline{E_2^{'}} \quad (13)$$

4. Result of electromagnetic field calculation and simulation

The transmission line operation will generate electromagnetic field radiation. The results of electromagnetic field radiation calculation and simulation for Raha - Baubau transmission line are presented below. The result of electric field radiation value using kV/m unit. The magnetic field radiation value using A/m unit, which later could be converted to Tesla value. The value of 1 A/m = 0.00126 mT.

Table 1. The value of electromagnetic field

No	X [m]	Y [m]	E [kV/m]	H [A/m]
1	-35	2	0.038491	0.47356
2	-34	2	0.041757	0.503942
3	-33	2	0.045518	0.536687
4	-32	2	0.049837	0.571993
5	-31	2	0.054777	0.610071
6	-30	2	0.060406	0.651146
7	-29	2	0.066792	0.695459
8	-28	2	0.074008	0.743263
9	-27	2	0.082124	0.79482
10	-26	2	0.091211	0.850404
11	-25	2	0.101335	0.910293
12	-24	2	0.112557	0.974765
13	-23	2	0.124923	1.044091
14	-22	2	0.138465	1.118525
15	-21	2	0.153191	1.198297
16	-20	2	0.169077	1.283592
17	-19	2	0.186059	1.374536
18	-18	2	0.20402	1.471174
19	-17	2	0.222785	1.573446
20	-16	2	0.242104	1.681156
21	-15	2	0.261651	1.793945
22	-14	2	0.281019	1.911259
23	-13	2	0.299719	2.032315
24	-12	2	0.3172	2.15608
25	-11	2	0.332867	2.281251
26	-10	2	0.346127	2.406249

Table 1. (*continued……*)

27	-9	2	0.356439	2.529232
28	-8	2	0.363391	2.648128
29	-7	2	**0.366778**	2.760685
30	-6	2	0.366683	2.864554
31	-5	2	0.363549	2.95738
32	-4	2	0.358203	3.036913
33	-3	2	0.351825	3.101121
34	-2	2	0.34581	3.148292
35	-1	2	0.341519	3.177133
36	0	2	0.339964	**3.186838**
37	1	2	0.341519	3.177133
.38	2	2	0.34581	3.148292
39	3	2	0.351825	3.101121
40	4	2	0.358203	3.036913
41	5	2	0.363549	2.95738
42	6	2	0.366683	2.864554
43	7	2	**0.366778**	2.760685
44	8	2	0.363391	2.648128
45	9	2	0.356439	2.529232
46	10	2	0.346127	2.406249
47	11	2	0.332867	2.281251
48	12	2	0.3172	2.15608
49	13	2	0.299719	2.032315
50	14	2	0.281019	1.911259
51	15	2	0.261651	1.793945
52	16	2	0.242104	1.681156
53	17	2	0.222785	1.573446
54	18	2	0.20402	1.471174
55	19	2	0.186059	1.374536
56	20	2	0.169077	1.283592
57	21	2	0.153191	1.198297
58	22	2	0.138465	1.118525
59	23	2	0.124923	1.044091
60	24	2	0.112557	0.974765
61	25	2	0.101335	0.910293
62	26	2	0.091211	0.850404
63	27	2	0.082124	0.79482
64	28	2	0.074008	0.743263
65	29	2	0.066792	0.695459
66	30	2	0.060406	0.651146
67	31	2	0.054777	0.610071
68	32	2	0.049837	0.571993
69	33	2	0.045518	0.536687
70	34	2	0.041757	0.503942
71	35	2	0.038491	0.47356

The above result shows that the largest electric field value occurring at two coordinate points (-7,2) and (7,2) with 0.366778 kV/m. The largest magnetic field occurred at coordinates (0,2) with 3.186838 A/m or 0.004 mT. The value of electromagnetic field radiation occurring was still below the specified standard value, 5 kV/m for the electric field and 0.1 mT for the magnetic field.

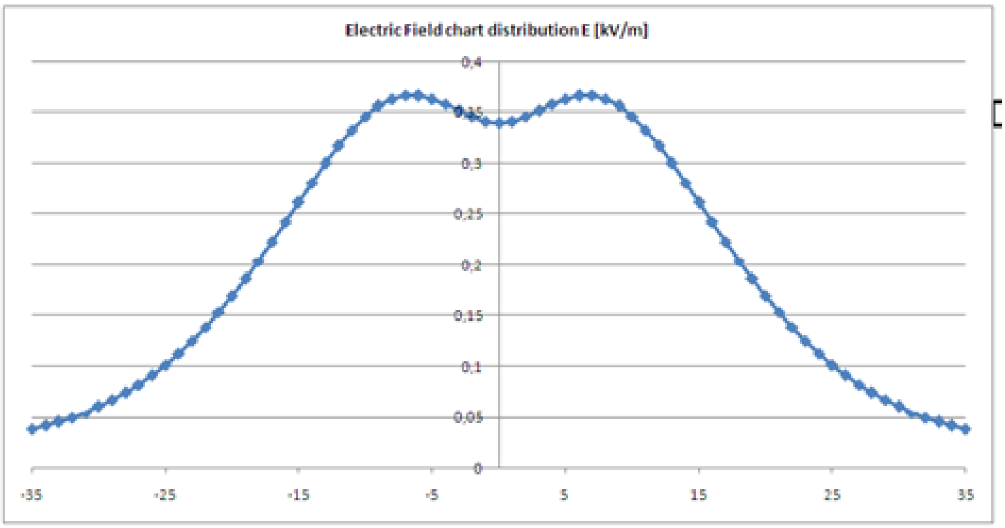

Figure 4. Electric Field Distribution Chart

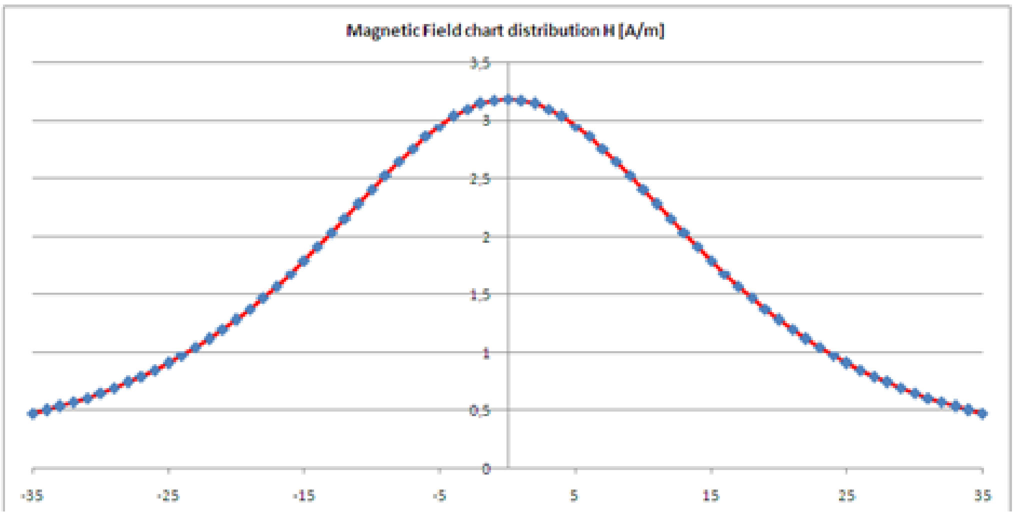

Figure 5. Magnetic Field Distribution Chart

5. Conclusion

1. The electric field radiation value of 150 kV Raha - Baubau transmission line were 0.038491 kV/m - 0.366778 kV/m.
2. The magnetic field radiation value of 150 kV Raha - Baubau transmission line were 0.47356 A/m - 3.186838 A/m.
3. Both electric field and magnetic field radiation value did not exceed the specified standard, 5 kV/m for electric field and 0.1 mT for magnetic field.

References

[1] Saadat H 2004*Power System Analysis*2nd edition (Singapore: McGraw-Hill Book).
[2] Glover J D and Sarma M S 2002*Power System Analysis and Design* 3rd edition (Boston: Brooks/Cole – Thomson Learning).
[3] Yusran 2014 *Proc.The 4th Makassar International Conf. on Electrical Engineering and Informatics* (*MICEEI*)*(Makassar)* (Canada: IEEE).
[4] Yusran, Ashari M and Soeprijanto A 2013 Optimization scheme of distributed generation installation growth considering network power quality *J. Theor. Appl. Inf.* **53** 30-39.
[5] The Minister of Energy and Mineral Resources Republic of Indonesia 2017 *Electricity Supply Business Plan 2017 – 2026* (Jakarta: PT PLN).
[6] Kraus and Carver 1973 *Electromagnetics*2ndEdition(New York: Mc Graw-Hill).
[7] Hayt Jr W H and Buck J A 2001 *Engineering Electromagnetics*6thEdition (New York: Mc Graw-Hill).
[8] Stevenson W D 1982 *Elements of Power System Analysis*4thEdition (New York: Mc Graw-Hill).