Jurnal
Teknologi

Full Paper

MAGNETIC FIELD MEASUREMENT FROM 132/275 KV OVERHEAD POWER LINES

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Article history
Received
27 January 2016
Received in revised form
15 November 2016
Accepted
10 December 2016

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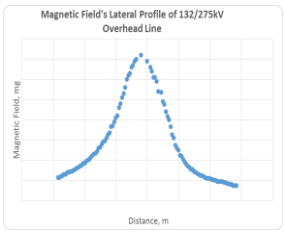
Graphical abstract



Abstract

This paper presents a study on magnetic field radiated from 132/275kV overhead power lines. The magnetic field radiation from overhead power lines have become a concern to the public due to its adverse health effects such as leukemia in children. A report from World Health Organization (WHO) stated that radiated magnetic fields from overhead power lines may cause leukemia in children if they are exposed to it every day. Therefore, the main objective of this study is to measure the magnetic field radiated from 132/275kV power lines. EMDEX II, a free body meter is used to measure the magnetic field at 1 meter above ground level and the lateral profile was proven using MATLAB calculation. The measurement was done at SJK (T) Gelang Patah and Taman Pulai Utama at a distance of 35 meter from the outermost conductor. The results from both locations show that the radiated magnetic field is much lower than the exposure limit stated in the ICNIRP standard, in which the highest data recorded is only 4mG. The lateral profile magnetic field also shows that exposure to magnetic fields directly below the overhead power line are within the ICNIRP recommended exposure limits. Thus, it can be concluded that the magnetic field radiated by 132/275kV power lines in Malaysia operate at a safe level.

Keywords: Magnetic fields, power lines, radiation, ELF, cancer

Abstrak

Radiasi medan magnet daripada talian kuasa elektrik telah menjadi satu kebimbangan kepada masyarakat kerana ianya boleh mendatangkan kesan buruk terhadap kesihatan contohnya seperti leukemia kanak-kanak. Laporan daripada WHO menyatakan bahawa medan magnet yang terhasil daripada talian kuasa elektrik berkemungkinan adalah satu penyebab kepada penyakit leukemia kanak-kanak jika mereka terdedah setiap hari. Oleh itu, objektif utama projek ini adalah untuk mengukur medan magnet yang terhasil daripada talian kuasa 132/275kV. EMDEX II adalah satu meter yang digunakan untuk mengukur medan magnet pada ketinggian 1 meter daripada tanah manakala profil sisian medan magnet dibuktikan melalui pengiraan menggunakan MATLAB. Pengukuran dilakukan di SJK (T) Gelang Patah dan Taman Pulai Utama pada jarak 35 meter daripada konduktor yang paling luar. Hasil dapatan daripada kedua-dua lokasi menunjukkan bahawa medan magnet daripada talian kuasa 132/275kV adalah jauh lebih rendah daripada had pendedahan yang dinyatakan dalam standard ICNIRP, yakni data tertinggi yang direkodkan adalah hanya 4.0 mG. Profil sisian medan magnet juga menunjukkan bahawa pendedahan medan magnet di bawah talian kuasa adalah pada tahap lingkungan had pendedahan yang disyorkan oleh ICNIRP. Oleh yang demikian, maka dapatlah disimpulkan bahawa medan magnet yang dihasilkan oleh talian kuasa 132/275kV di Malaysia adalah berada pada tahap yang selamat.

Kata kunci: Medan magnet, talian kuasa, *radiasi,* ELF, kanser

1.0 INTRODUCTION

Malaysia is a developing country with growing and expanding cities. Consequently, the overhead power lines which used to be placed far from people, is now closer to the residential and occupational area as these areas have expanded. Today, people live and work near overhead power lines and are potentially in harm's way due to the radiated magnetic fields being emitted from the power lines. There are many individuals who do not understand the risk of being harmed by magnetic field radiation. Until today, it was still uncertain how magnetic field radiation may affect human health. It has attracted the attention of many researchers who continuously investigate this matter. This is a critical problem for people who are currently living and working close to overhead power line.

Adverse health effects from magnetic field radiation have become a concern for most of countries around the world. Previously, most studies found no indication that magnetic field radiation from overhead power lines has serious impacts on human health, but recent studies show contradictory results. Many recent scientific studies indicate that there is a possibility of increasing the likelihood of cancer occurring in children within populations that live near overhead power lines [1,2,4]. High voltage levels are believed to increase the risk of overexposure to magnetic field, especially in children [1]. Another study found that a low frequency magnetic field can induce circulating currents within the human body [2]. The intensity of the outside magnetic field determines the strength of these currents. If the magnetic field is sufficiently large, these currents may cause a stimulation of the nerves and muscles and/or affects other biological processes. Farag *et al*. [3] discusses electromagnetic field exposure in an assessment of 5 public schools in Malaysia, where the level of electromagnetic fields at those selected areas was determined. Sahbudin *et al*. [4] has analysed and computed the amount of electrical potential, electric and magnetic field density at certain points and distances from 132kV and 275kV overhead high voltage power lines in Malaysia. According to the statement released by WHO in 2007 [5], everyday exposure to chronic low-intensity (above 3 mG to 4 mG) ELF magnetic fields may increase health risks, potentially leading to leukaemia, especially in children.

Although scientific evidence is not strong enough to be considered causal, it is sufficiently strong enough for it to remain a concern. Other diseases such as depression and reproductive dysfunction, as well as other forms of cancers, have also been studied for possible association with ELF magnetic field exposure, but scientific evidence does not support this [5]. Meanwhile according to International Agency for Research on Cancer or IARC [6], it was stated that an extremely low frequency magnetic field was classified as "possibly carcinogenic". This conclusion was made based on "limited" evidence from humans concerning childhood leukaemia, "inadequate" evidence from humans concerning all other cancer types, and "inadequate" evidence from animals.

In Malaysia, overhead power lines are divided into two types; these are transmission lines and distribution lines and they usually operated at 132kV, 275kV and 500kV. Both transmission lines and distribution lines generate strong magnetic fields [7]. The most common type of tower used in Malaysia is the double circuit (Figure 1) type that carries two circuits of three phase conductors. Each side of the tower is arranged with three phases of conductors in vertical position, while the quadruple tower (Figure 2) can carry four circuits instead of two. Therefore, each side of the tower will have two circuits; two circuits on the left, and another other two circuits on the right [8].

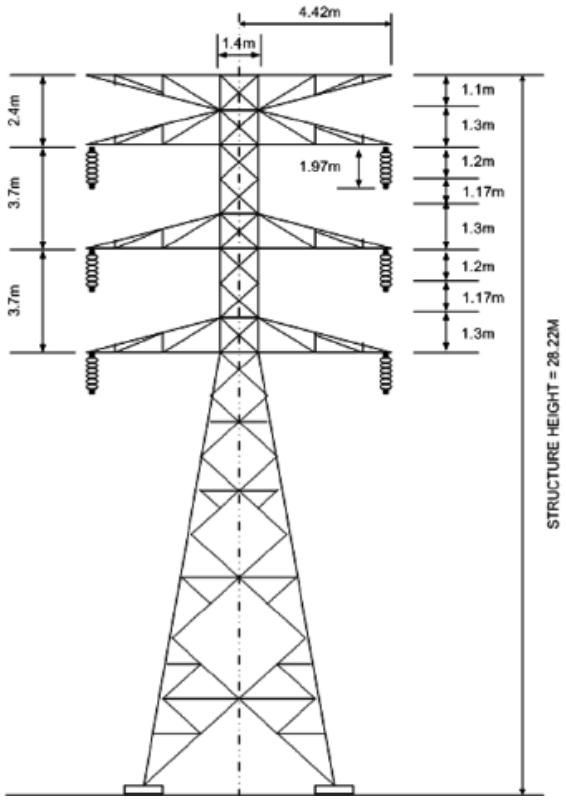


Figure 1 Double circuit power line (figure adapted from [9])

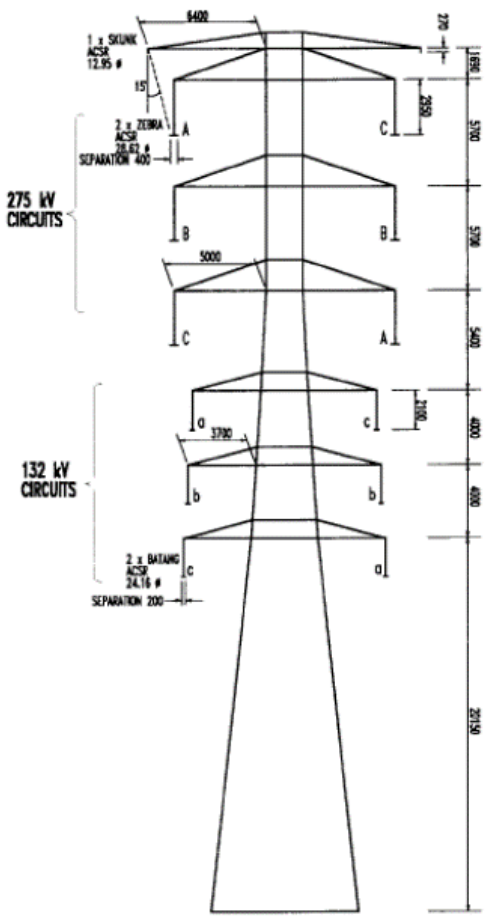


Figure 2 Quadruple circuit power line (figure adapted from [10])

When expanding a new power grid, the design engineer needs to consider the priority of the location so that residences in the vicinity of that area are affected as little as possible by the radiated magnetic field. Figure 3 is a guideline for engineers to take into account when a selection or combination is "appropriate and justified in a given situation" during the planning process. Low priority areas are identified by little to no public exposure, while high priority areas are among highly population areas and remain to be a public concern [11].

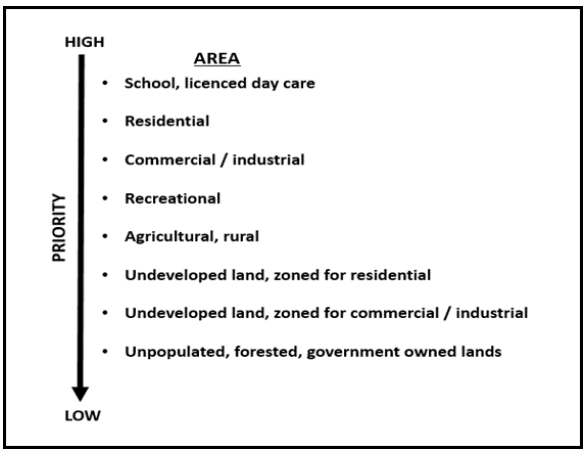


Figure 3 Area prioritization for electromagnetic field exposure [11]

2.0 MEASUREMENT

i) Magnetic Field Measurement

As far as authors concern, this study is the first to investigate the magnetic field radiation close to the school and residential area in Johor. Measurement of the magnetic field was done according to the requirements set by ANSI, IEEE standard 644-1987 [13] and the data measured was compared to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines 2010 [14]. All measurements were taken at 1m above ground level. Measurements were done at two locations; in the vicinity of SJK (T) Gelang Patah (single 132/275kV quadruple circuit line tower) and in the residential area of Taman Pulai Utama, Johor Bahru (double 132/275kV quadruple circuit line tower). The data was recorded at 35m from the outermost conductor of the overhead power lines in both locations. Thirty five meters (35m) is where the nearest human activity lies in relation to the power lines, and represents the highest level of magnetic field radiation that people might be exposed to. The time of measurements is tabulated in Table 1.

Table 1 Measurement Time

Location	Measurement Time (hours)	Day
SJK (T) Gelang Patah	1030-1230 1400-1600	
Taman Pulai Utama Residential Area	1030-1230 1400-1600 2000-2200	Monday

The magnetic field in this study was measured using EMDEX II exposure meter as shown in Figure 4.. It is important to measure the magnetic field without the E-Probe's plates in order to maintain the accuracy of the measurement. This is because the

magnetic field levels recorded will be slightly lower if the measurement is taken while using EMDEX II meter attached to the E-Probe.

Figure 4 EMDEX II Meter [12]

ii) Lateral Profile Measurement

The lateral profile of the magnetic field of an overhead power line was measured at selected intervals in a direction parallel to the line at 1m above ground level. The measurement of the lateral (half) is taken from the mid-span of the overhead lines (see Figure 5) and made to follow a lateral distance of up to 30m beyond the outside conductor. Measurements under the conductor were performed at least for five equally spaced distances. A complete profile measurement has to be done for both sides of the tower. In order to determine if adequate details have been obtained during the measurement, the measuring field profiles were plotted. Repeating the measurement at intermediate times will provide some indication of possible changes in line height, load or voltage. During the measurement, local time was recorded to facilitate later review of the data, together with the line voltage and load data from the substation.

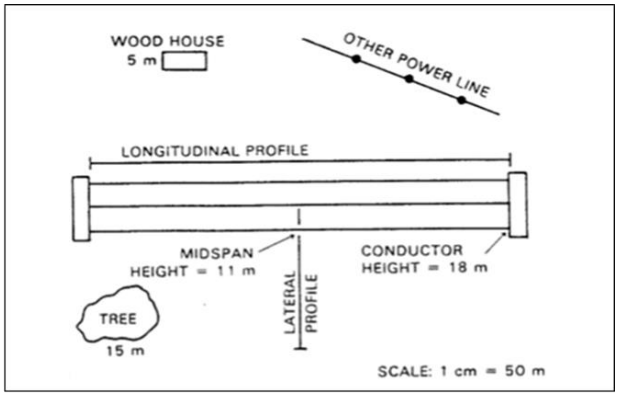


Figure 5 Lateral profile measurement [13]

iii) Modelling of 132/275 kV Quadruple circuit overhead powerline.

In this study, MATLAB software was used to write a simple program for magnetic field calculations from 132/275kV overhead power lines in order to plot a magnetic field's lateral profile graph. The graph plotted from MATLAB is then compared to the actual results from the site measurement. The dimension of the overhead power line is displayed in Figure 6. It was modelled using data obtained from Tenaga Nasional Berhad (TNB). There are 12 pairs of (24) conductors for 132/275kV quadruple circuit lines. Each pairs of 132kV and 275kV are spaced 300mm and 400mm apart. Rated current flow in each conductor for 132kV and 275kV are 729 A and 1232 A, respectively. To determine the magnetic field at a given distance from the overhead power line, the distance from a set of point to all 24 conductors need to be known. The conductors are label a11, a12, a21, a22, b11, b12, b21, b22 and so on until the letter 'f', as shown in Figure 6. The program was set for the calculation of magnetic field along 1m above ground level.

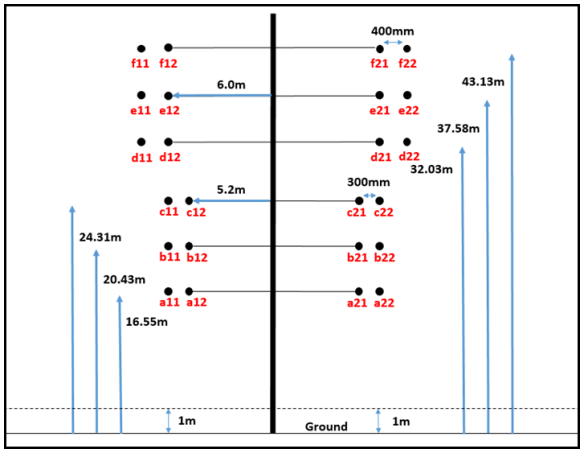


Figure 6 132/275kV overhead line dimension

To calculate the magnetic field, the following equation (1), (2) and (3) [15] are used in the program. Results for equation (1) and (2) depend on the number of conductors on the line and the distance of all the conductors from a given point along the 1m line. Since there are 24 conductors, there will be 24 values of each (B_x) and (B_y). The resulting magnetic values are calculated using Equation (3). The rated current with its respected angle (Figure 7) will be used in the calculation.

$$B_x = \sum_{j=1}^{n} \frac{\mu_0 * I_j * y_j}{2\pi(x_j^2 + y_j^2)} \quad (1)$$

$$B_y = \sum_{j=1}^{n} \frac{\mu_0 * I_j * x_j}{2\pi(x_j^2 + y_j^2)} \quad (2)$$

$$Magnetic\ Field\ |B| = \sqrt{|B_x|^2 + |B_y|^2} \quad (3)$$

Where;
B_x = x-axis magnetic field component
B_y = y-axis magnetic field component
$|B|$ = Resultant magnetic field
μ_0 = Magnetic constant (permeability of free space)
I_j = Current flowing through the conductor
x_j = The distance of conductor from the tower
y_j = The height of conductor from ground

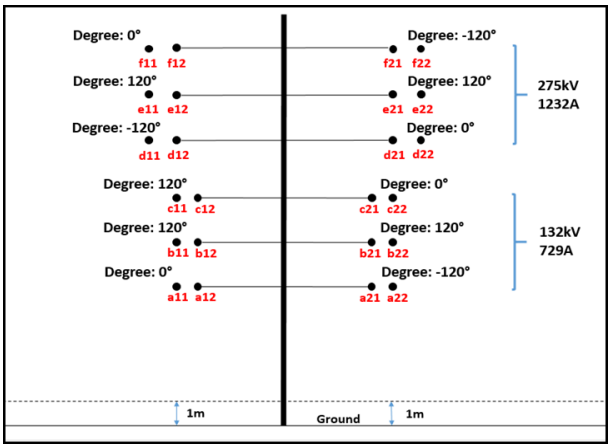


Figure 7 Voltage and current phasing arrangement of 132/275kV overhead line

3.0 RESULTS AND DISCUSSION

The magnetic field data recorded for 1m above ground level and 35m from the overhead power lines' outermost conductor at both locations is shown in Table 2, Table 3 and Table 4, respectively. The highest data measured on Monday in SJK (T) Gelang Patah was 3.8 mG while in Taman Pulai Utama it was 4 mG. Compared to the ICNIRP's exposure guideline limits, which is 2G [14], the magnetic field readings at both locations are only 0.18 % and 0.2 % of the ICNRP's value. This value is much lower than the exposure limits. However, when compared to the report from WHO, which stated that 'daily exposure to more than 3-4mG magnetic field can cause childhood leukemia'[5], it is shown that exposure to the magnetic field at both locations mat affect children's health, especially when considering the fact that it is a school and residential area.

Meanwhile, the magnetic field's lateral profile from both locations were measured to observe the magnetic field activities under the overhead lines with respect of its distance. It was measured perpendicularly to the overhead line from the mid-span at equally spaced distances. The measurement was taken at every 1m to obtain accurate data. The data was then plotted using Microsoft Excel to form the lateral profile graph. Some of the data was excluded when plotting the graph in order to get the best fit line graph.

Table 2 Magnetic field at 10.30am-12.30pm and 2pm-4pm (SJK (T) Gelang Patah)

Time	Magnetic Field (mG)	Time	Magnetic Field (mG)
1030	3.8	1400	3.7
1040	3.8	1410	3.7
1050	3.8	1420	3.7
1100	3.7	1430	3.7
1110	3.8	1440	3.7
1120	3.8	1450	3.8
1130	3.7	1500	3.7
1140	3.8	1510	3.7
1150	3.7	1520	3.8
1200	3.7	1530	3.8
1210	3.7	1540	3.7
1220	3.7	1550	3.7
1230	3.7	1600	3.7

Table 3 Magnetic field at 10.30am-12.30pm and 2pm-4pm (Taman Pulai Utama)

Time	Magnetic Field (mG)	Time	Magnetic Field (mG)
1030	4.0	1400	3.8
1040	3.9	1410	3.8
1050	3.9	1420	3.9
1100	3.8	1430	3.9
1110	3.9	1440	3.8
1120	3.8	1450	3.9
1130	3.9	1500	3.9
1140	4.0	1510	3.9
1150	3.9	1520	4.0
1200	3.9	1530	3.9
1210	3.8	1540	3.8
1220	3.8	1550	3.8
1230	3.8	1600	3.8

Table 4 Magnetic field at 8pm-10pm (Taman Pulai Utama)

Time	Magnetic Field, mG
2000	3.9
2010	3.9
2020	3.9
2030	3.8
2040	3.8
2050	3.8
2100	3.8
2110	3.7
2120	3.7
2130	3.6
2140	3.6
2150	3.6
2200	3.5

The graph in Figure 8 shows the lateral profile obtained from SJK (T) Gelang Patah, while the graph in Figure 9 shows the lateral profile obtained from Taman Pulai Utama. Point '0' is the center of the overhead power line. Generally, it shows a reduction in the magnetic field when distance from the centre of the power head line is increased. Theoretically, the magnetic field will gradually become zero when it is far enough from the overhead power line, as explained by Biot-Savart's law where the magnetic field intensity is inversely proportional to the distance.

Based on results depicted in Figure 8 and 9, it can be seen that the highest recorded data is around 14-15mG. This indicates that even below the overhead lines, the magnetic fields are still within the exposure limit recommended by ICNIRP.

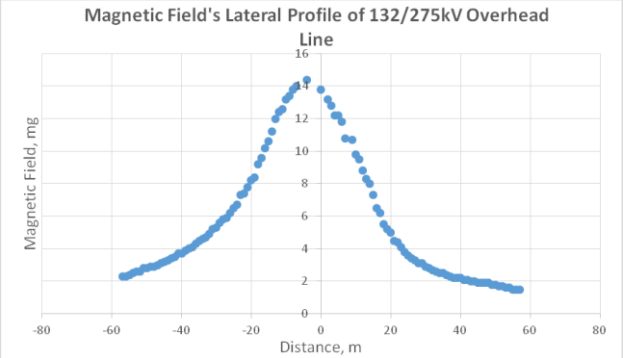


Figure 8 Lateral profile of 132/275kV overhead power line at SJK (T) Gelang Patah

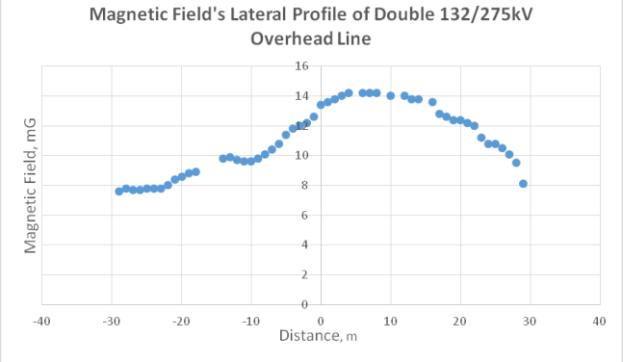


Figure 9 Lateral profile of 132/275kV overhead power line at Taman Pulai Utama

In order to verify the measurement results of this study, magnetic field calculations for quadruple circuit overhead power lines was done using MATLAB (Figure 10). Similar to the results depicted in Figure 8 and 9, it is shown that the magnetic field value is higher at the bottom of the overhead line and gradually decreases as distance increases. Since the rated current was used in the calculation, the graph shows the maximum possible value of magnetic field radiation at 1m above ground.

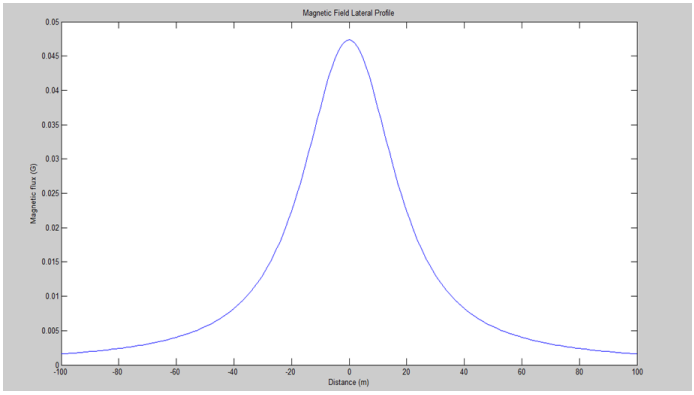


Figure 10 Calculated magnetic field lateral profile graph using MATLAB

4.0 CONCLUSION

From this study, the magnetic field of single and double tower 132/275kV overhead power lines were measured from 1m above ground level using EMDEX II meter. The result shows that the magnetic field from single and double tower 132/275kV overhead power lines are lower than the ICNIRP recommended exposure limit. The magnetic field radiated from 132/275kV overhead power lines can be concluded as safe and within the exposure limits recommended by ICNIRP. With regards to the report released by WHO, a link has been made between the exposure to magnetic field radiation in either locations and an increase in the likelihood of developing childhood leukemia, if children are exposed to it every day. The coupling effects (interaction between the electric and magnetic fields) also need to be considered as they might affect the body. To minimize the exposure to magnetic field radiation, communities are advised to keep a safe distance from overhead power lines. By minimizing the magnetic field exposure, it will reduces the risk of adverse health effects associate overhead power lines.

Acknowledgement

Authors would like to thank the technical staffs of Institute of High Voltage & High Current (IVAT), Universiti Teknologi Malaysia for their help during the field measurement. This work was supported by FRGS grant, no. 4F672 and GUP grant no. 07H13 and 13H96. Support given by the principal of SJK (T) Gelang Patah, as well as the teachers and other staffs during the site measurement at the school is highly appreciated.

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