Analysis of Electric Field and Magnetic Field from Overhead Subtransmission Lines Affecting Occupational Health and Safety in MEA's Power System

Att Phayomhom, Tirapong Kasirawat, Surasak Phontusa, Jarin Halapee, Boonserm Ainsuk, Kiatiyuth Kveeyarn, Nattachote Rugthaicharoencheep and Arwut Puttarach

Abstract— *Over the past decades up until the presence, the overhead subtransmission and distribution electricity networks within the cities are mainly overhead lines, owing to the lower construction costs in comparison with the high construction costs of the undergrounding of electricity lines. Also, due to the substantial urban development in the present time, a lot of towns, streets, factories, and etc. have increased significantly. This urbanization has led to the construction of buildings being built near power lines, which are the source that produces both electric and magnetic fields (EMFs).*

Therefore, this research aims at studying the values of EMFs, in which level that can have the adverse effects on health and analysing the limits on the exposure of the public to EMFs, which are produced by the different arrangement of conductors of the 69 kV and 115 kV high voltage subtransmission lines. Moreover, the computer-supported calculation program as Microsoft Excel is an essential tool to help analyse the values of EMFs and present the results of the analysis through graphics with the Matlab program. Matlab is used as the graphics supporting to plot values and intensity of EMFs in the form of surface and contour graphs to help have an easy understanding and to help in interpretation of EMFs around the conductors.

Secondly, examining whether the derived values of EMFs gotten from each specific arrangement of conductors are acceptable in comparison with the maximum 50 Hz EMFs recognised by Metropolitan Electricity Authority (MEA) and International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Finally, studying the relation between a reduction of EMFs' intensity around the subtransmission lines and the negative effects on health produced by EMFs. The results of this research is to determine safety parameters or limits of EMFs and the safety clearance from the conductors.

Keywords— **Electric field, magnetic field, occupational health and safety, subtransmission line.**

1. INTRODUCTION

Metropolitan Electricity Authority (MEA) is an electric utility that is responsible for power distribution covering an area of 3,192 square kilometers in Bangkok, Nonthaburi, and Samutprakarn provinces of Thailand. MEA's power networks consist of transmission, subtransmission and distribution systems. The transmission line voltage is 230 kV, while 69 and 115 kV is subtransmission line voltages, and 12 and 24 kV are defined as distribution level as shown in Fig. 1.

Approximately 90% of MEA's distribution networks are overhead lines. In case of subtransmission and distribution line are to be on the same route, due to the limitation of right of way, economy etc distribution lines have to be installed at the same poles as that of the subtransmission's, but of different height. As a result, distribution lines are placed at the lower part of the pole, subtransmission lines are placed at the upper part, and an OHGW hung as shield wire between pole to pole to protect lightning surge [1]. This research aim to study on the effect of EMFs whether which level affect to human being condition base on ICNIRP standard.

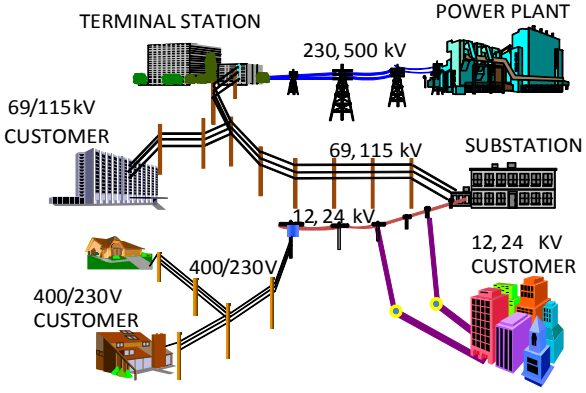

Fig. 1. MEA Power's Distribution System.

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Att Phayomhom (corresponding author) is with Power System Planning Department, Metropolitan Electricity Authority (MEA), 1192 Rama IV Rd., Klong Toey, Bangkok, 10110, Thailand. Phone: +66-2-348-5629; Fax: +66-2-348-5133; E-mail: att_powermea@hotmail.com, attp@mea.or.th.

Kiatiyuth Kveeyarn is with the Department of Electrical Engineering, Faculty of Engineering, Kasetsart University, 50 Ngam Wong Wan Rd., Ladyao, Chatuchak, Bangkok, 10900, Thailand. Phone: +66-2-797-0999 ext.1516; E-mail: fengkyk@ku.ac.th.

Nattachote Rugthaicharoencheep is with the Department of Electrical Engineering, Faculty of Rajamangala University of Technology Phra Nakhon, 1381, Pibulsongkram Rd., Bangsue, Bangkok, 10800, Thailand. Phone: +66-2 - 913-2424 Ext. 150; E-mail: nattachote.r@rmutp.ac.th.

Arwut Puttarach is with the Department of Electrical Engineering, Faculty of Rajamangala University of Technology Lanna, 128 Huay Kaew Road, Muang, Chiang Mai, Thailand, 50300, Thailand. E-mail: a.puttarach@gmail.com.

2. TWO DIMENSIONS ELECTRIC AND MAGNETIC FIELDS CALCULATION PRINCIPLE

Generally, electric and magnetic fields can be calculated in several methods. It depends on the complication of the system. The uncomplicated system works with mathematic equation but another one can't be expressed in one equation. It's needed iterative calculation by computer such as finite element method or boundary element method. Not only complication of the system but also dimensions (2 dimensions or 3 dimensions) has been used to separate the calculation method. Since the high voltage overhead subtransmission system is uncomplicated, therefore; electric and magnetic fields can be calculated by 2 Dimensions Orthogonal Coordinates together with Superposition Theorem. This principle divided electric and magnetic fields into two elements which are real part (X axis) and imaginary part (Y axis). Then, sum up all of these elements in each axis. Finally, calculate the result of the electric field from both axes.

Electric and magnetic fields calculation is presenting a characteristic of the electric field around the overhead subtransmission line in an open-air area. The result leads the system designer to aware whether what kind of effect might come after. By the way, the result given by using this calculation method has lower accuracy than measuring the field onsite [2-4].

Condition and Limitation of Two Dimensions Electric Field Calculation

Two dimensions electric field around the overhead subtransmission line can be calculated within these condition and limitation as follows [2-4]:

- The calculated area must be an open-air area and electric field refraction is neglected. The refraction is caused by electric pole, building, tree and etc. due to the characteristic of materials (resistive or conductive materials).
- Must know the values of voltage magnitude and phase angle of all feeder lines including overhead ground wire compare with ground.
- Must know the conductors size, in case of bundle conductors; it needs more parameters which are quantities and spaces of the conductors.
- Must know height and distance of the conductors from reference point.
- Assuming that the conductor lengths are infinity and its arrangement is perfectly parallel between conductors and ground also. Sag and incline of the conductors are neglected.

Condition and Limitation of Two Dimensions Magnetic Field Calculation

Two dimensions magnetic field around the overhead subtransmission line can be calculated within these condition and limitation as follows [2-4]:

- Must know the values of voltage magnitude and phase angle of all conductors.
- Must know height and distance of the conductors from reference point.
- Current flows in the same direction.
- Assuming that the conductor lengths are infinity and its arrangement is perfectly parallel between conductors and ground also. Sag and incline of the conductors are neglected.

3. ELECTRIC AND MAGNETIC FIELDS SAFETY STANDARD

MEA has installed electric power subtransmission system by controlling electric and magnetic fields within safety value in accordance with World Health Organization (WHO) standard. WHO has been working with International Commission on Non-Ionizing Radiation Protection (ICNIRP) for research and development. They have been researching on environmentally safety for people within electromagnetic field from low frequency system (50 Hz). The results, maximum electric and magnetic field are shown in Table 1 [5].

Table 1. Electric and Magnetic Fields Safety Criteria of MEA

Location	Period	Electric Field (kV/m)	Magnetic Field (mG)
Establishment	Working hours	10 kV/m	5,000
Public	All day	5 kV/m	1.000

4. CASE STUDY

Electric field results of 69 kV subtransmission system

Table 2. Electric and Magnetic Field Parameters for 69 kV Single Circuit 2-Bundled Conductor

Phase	Height of Conductor (m)	Distance from Center of Electric Pole (m)	Voltage (V)	Current (A)	Phase Angle	Diameter of Conductor (m)
R	16	1.4	39,837.17	1,600	0	0.02265
Y	14.17	1.4	39,837.17	1,600	-120	0.02265
B	12.34	1.4	39,837.17	1,600	-240	0.02265
OHGW	17.63	0.15	0	0	0	0.00794

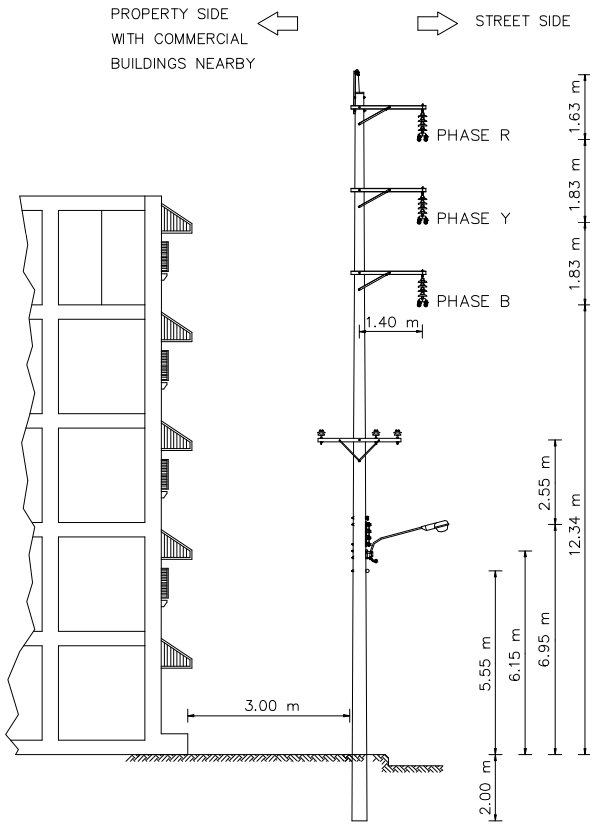

Fig.2. Subtransmission Line Arrangement for 69 kV Single Circuit 2-Bundled Conductor [6].

Then, calculate electric field as mentioned above. The results are shown in Figs.3-5.

This level is maximum height beneath subtransmission line which electric field still within safety criteria for 69 kV subtransmission line.

This level is minimum height above subtransmission line which electric field is within safety criteria for 69 kV subtransmission line.

The results show that electric field at each height which show in Figs.3-5 are safe.

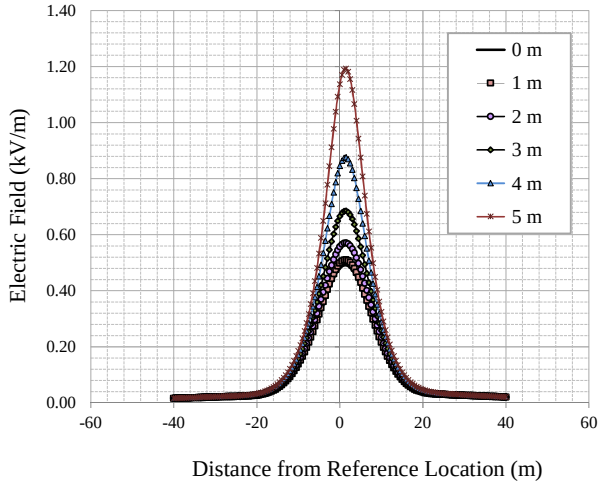

Fig. 3. Electric Field at Each Height above Ground for 69 kV Subtransmission Line.

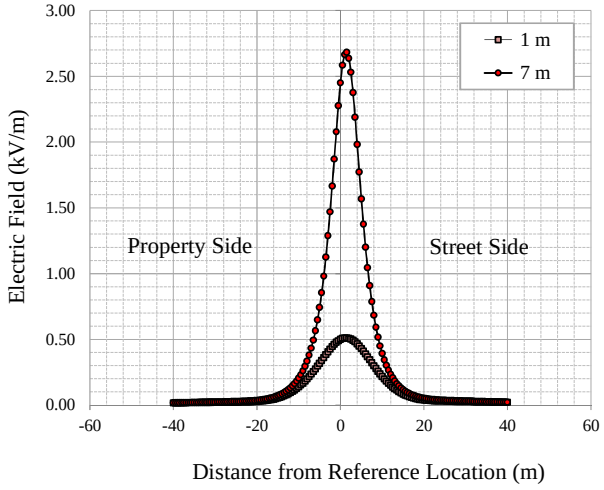

Fig. 4. Electric Field at 7 meters Height above Ground for 69 kV Subtransmission Line.

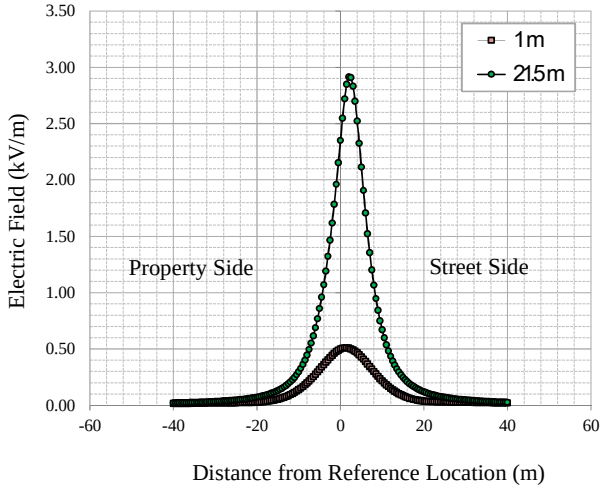

Fig. 5. Electric Field at 21.5 meters Height above Ground for 69 kV Subtransmission Line.

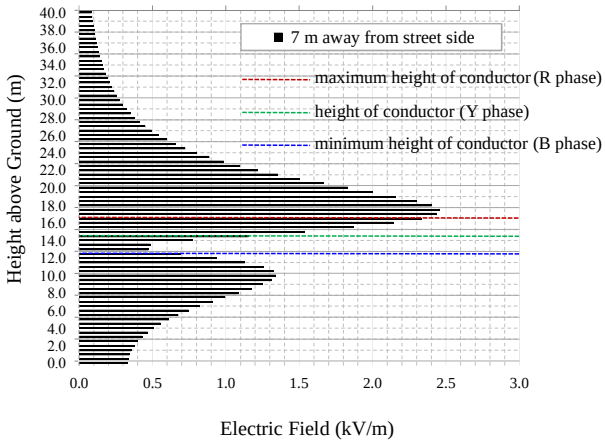

Fig. 6. Electric Field at Each Height above Ground Focusing on the Street Side for 69 kV.

At 7 meters away, this distance is the nearest which electric field is within safety criteria of 69 kV subtransmission line.

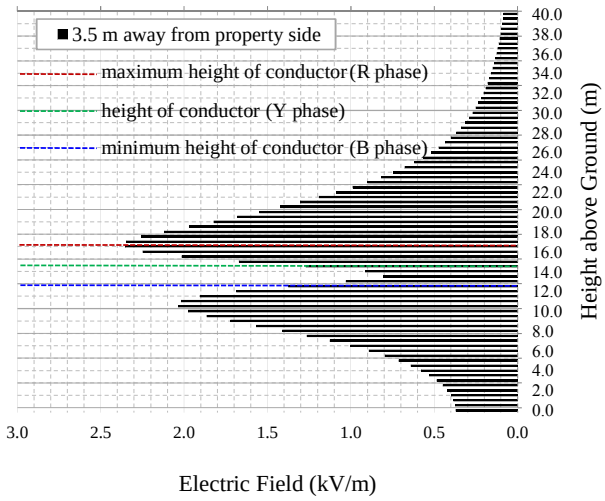

Fig. 7. Electric Field at Each Height above Ground Focusing on the Property side for 69 kV.

At 3.5 meters away, this distance is the nearest which electric field is within safety criteria of 69 kV subtransmission line.

Considering on the street side in Fig.6 and the property side in Fig.7, the results show that at 17.5 meters high above ground which is the same level as phase R; electric field value is maximum but still within safety criteria.

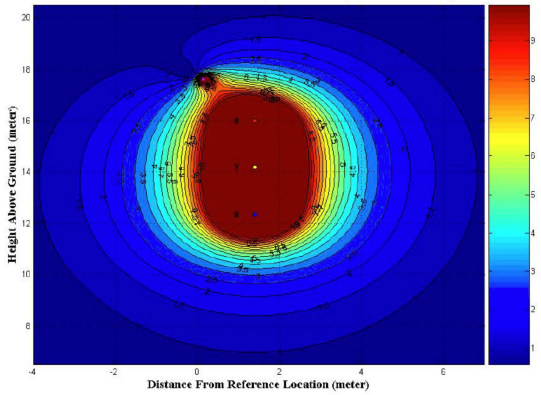

Fig.8. Electric Field Around 69 kV Conductor Carry Out by Matlab Software.

The result of electric field around 69 kV can be shown in a graph format. It's plotted by Matlab software as shown in Fig.8.

Electric field results of 115 kV subtransmission system

Then, calculate electric field as mentioned above. The results are shown in Figs.10-14.

This level is maximum height beneath subtransmission line which electric field still within safety criteria for 115 kV subtransmission line.

This level is minimum height above subtransmission line which electric field is within safety criteria for 115 kV subtransmission line.

Table 3. Electric and Magnetic Field Parameters for Type 115 kV Single Circuit 2-Bundled Conductor

Phase	Height of Conductor (m)	Distance from Center of Electric Pole (m)	Voltage (V)	Current (A)	Phase Angle	Diameter of Conductor (m)
R	18.30	1.9	66,397.23	1,600	0	0.02265
Y	15.80	1.9	66,397.23	1,600	-120	0.02265
B	13.30	1.9	66,397.23	1,600	-240	0.02265
OHGW	21.80	0.15	0	0	0	0.00794

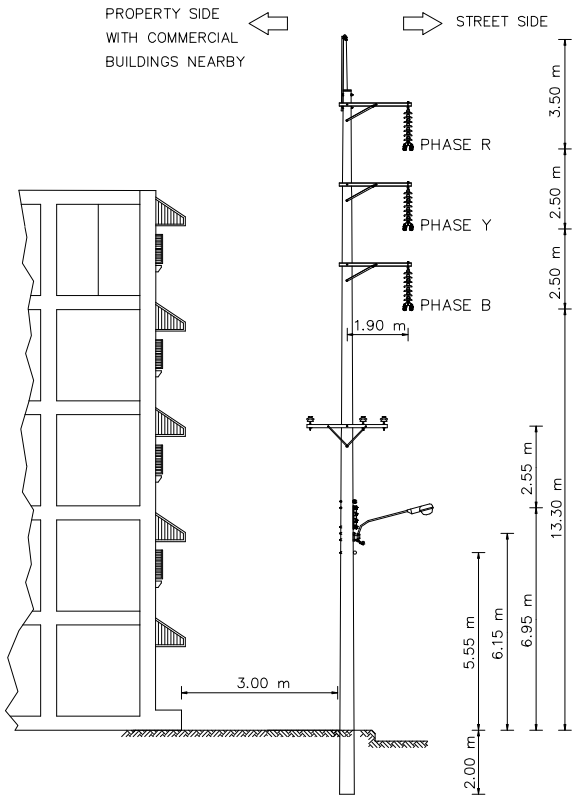

Fig.9. Subtransmission Line Arrangement for 115 kV Single Circuit 2-Bundled Conductor [7].

At 5 meters away, this distance is the nearest which electric field is within safety criteria of 115 kV subtransmission line.

From Fig. 11-12 showing maximum value of electric field but the value is still within safety criteria. From Fig. 13-14, at 18.3 meters above ground of property side and street side. This level has the same height as R phase conductor. So, maximum value of electric field located at this point but still within safety criteria.

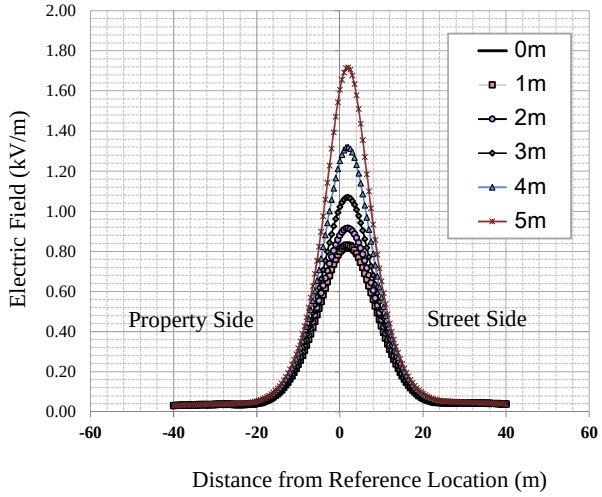

Fig.10. Electric Field at Each Height above Ground for 115 kV Subtransmission Line.

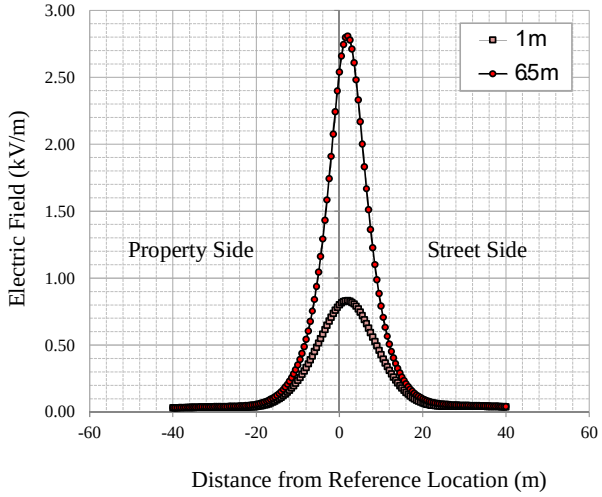

Fig.11. Electric Field at 6.5 meters Height above Ground for 115 kV Subtransmission Line.

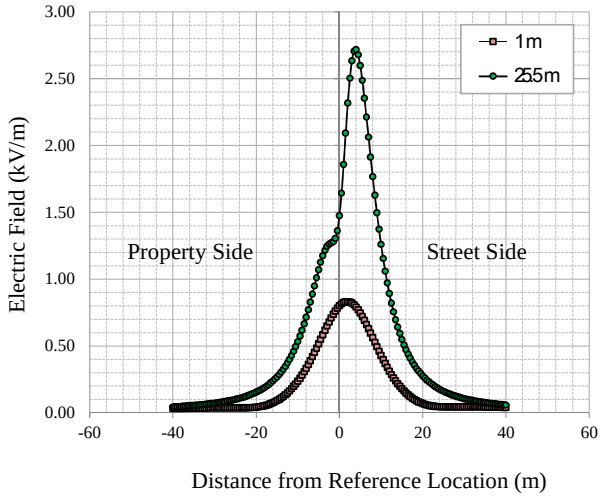

Fig.12. Electric Field at 25.5 meters Height above Ground for 115 kV Subtransmission Line.

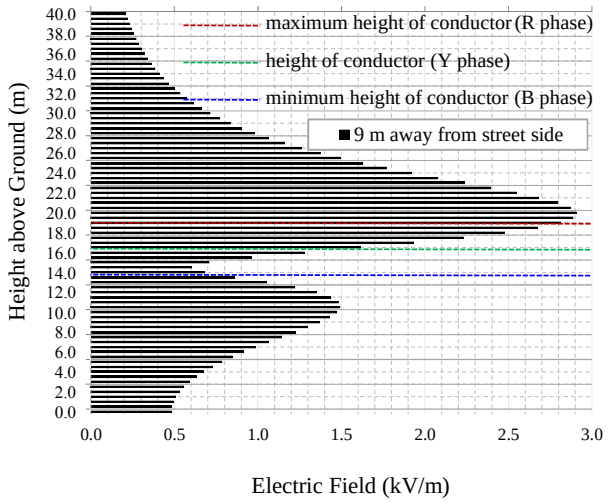

Fig.13. Electric Field at Each Height above Ground Focusing on the Street Side for 115 kV.

At 9 meters away, this distance is the nearest which electric field is within safety criteria of 115 kV subtransmission line.

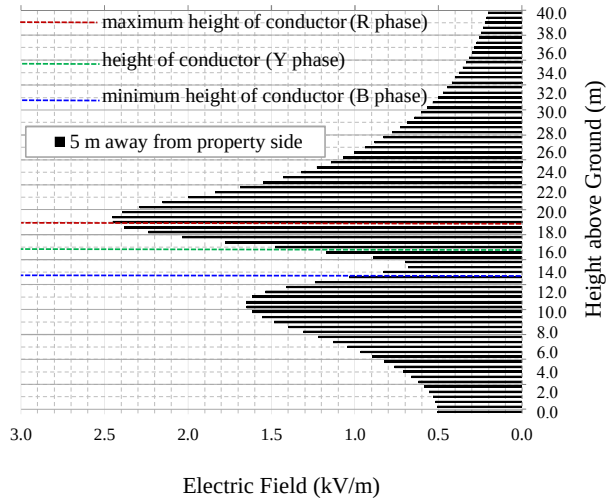

Fig.14. Electric Field at Each Height above Ground Focusing the Property Side for 115 kV.

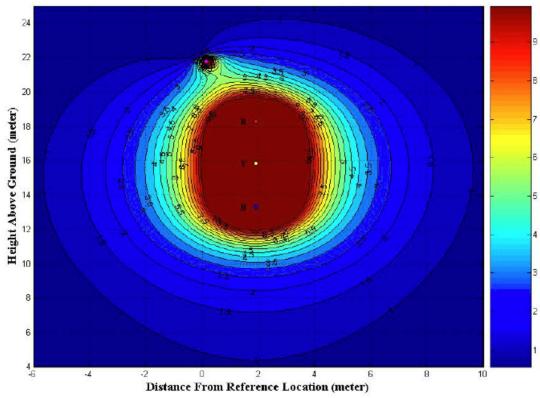

Fig. 15. Electric Field Around 115 kV Conductor Carry Out by Matlab Software.

The result of electric field around 115 kV can be

shown in a graph format. It's plotted by Matlab software as shown in Fig.15.

Magnetic field results of 69 kV subtransmission system

Magnetic field results of subtransmission system type 69 kV single 2-bundled. The results are shown as follows:

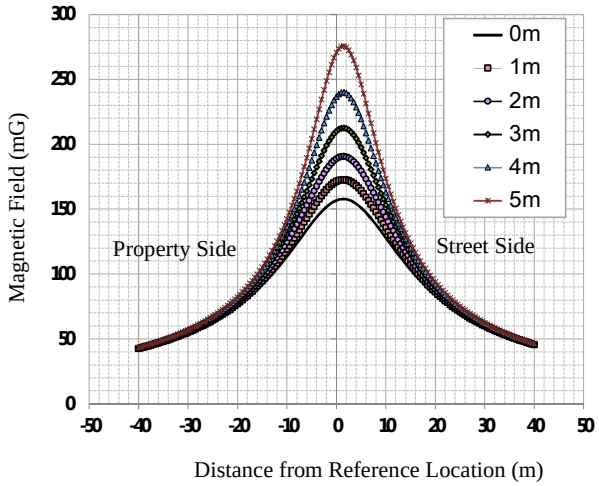

Fig.16. Magnetic Field at Each height above Ground for 69 kV Subtransmission Line.

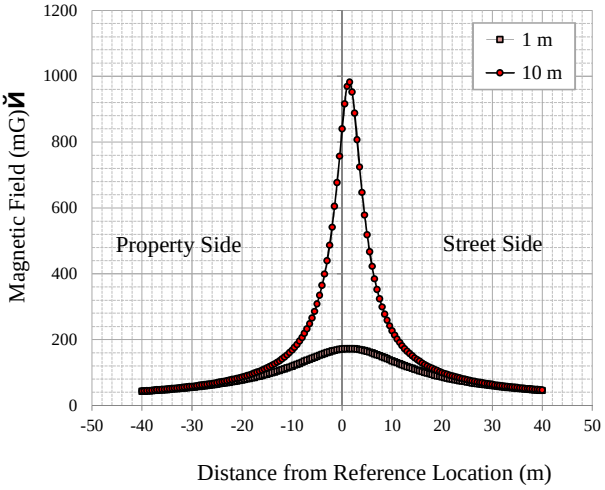

Fig.17. Magnetic Field at 10 meters Height above Ground for 69 kV Subtransmission Line.

This level is maximum height beneath subtransmission line which magnetic field still within safety criteria for 69 kV subtransmission line.

At 4.5 meters away, this distance is the nearest which magnetic field is within safety criteria of 69 kV subtransmission line.

At 1.5 meters away, this distance is the nearest which magnetic field is within safety criteria of 69 kV subtransmission line.

Magnetic field results of 69 kV within condition and limitation above show that maximum value of magnetic field located at 12.5 meters above ground and 1.5 meters away from property side.

This level is minimum height above subtransmission line which magnetic field is within safety criteria for 69 kV subtransmission line.

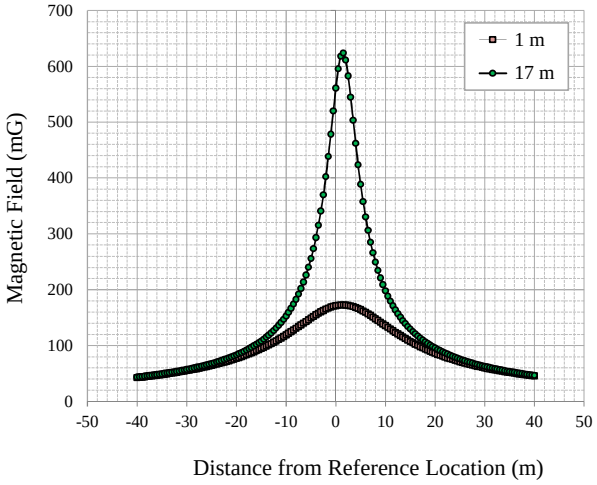

Fig. 18. Magnetic Field at 17 meters Height above Ground for 69 kV Subtransmission Line.

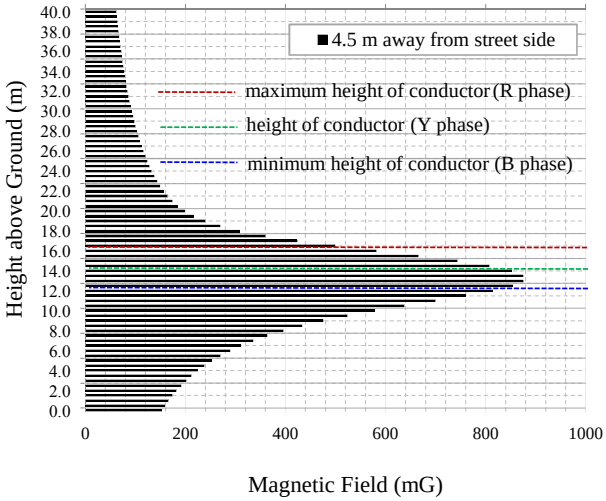

Fig.19. Magnetic Field at Each Height above Ground Focusing on the Street Side for 69 kV.

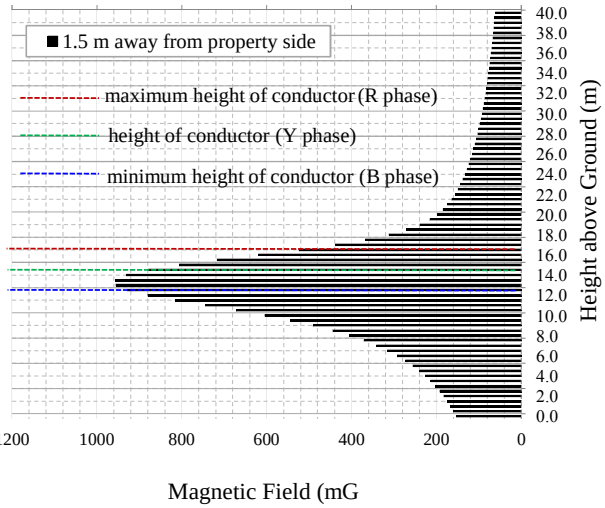

Fig. 20. Magnetic Field at Each Height above Ground Focusing the Property side for 69 kV.

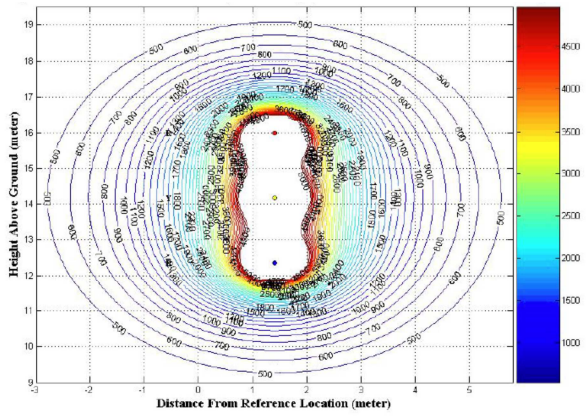

Fig. 21. Magnetic Field Around 69 kV Conductor Carry Out by Matlab Software.

The result of magnetic field around 69 kV can be shown in a graph format. It's plotted by Matlab software as shown in Fig.21.

Magnetic field results of 115 kV subtransmission system

Magnetic field results of subtransmission system type 115 kV single 2-bundled. The results are shown as follows:

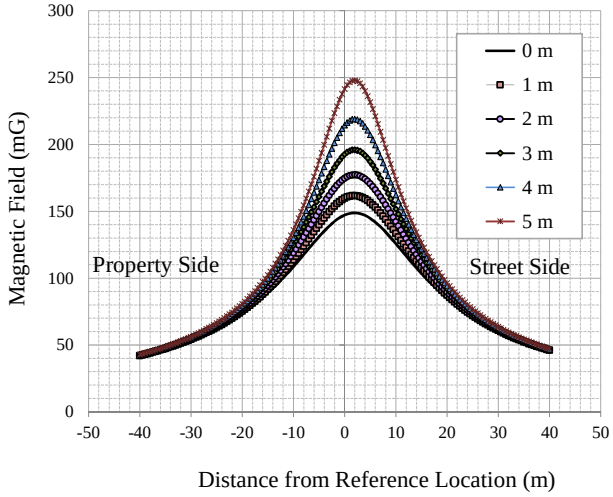

Fig.22. Magnetic Field at Each Height above Ground for 115 kV Subtransmission Line.

This level is maximum height beneath subtransmission line which magnetic field still within safety criteria for 115 kV subtransmission line.

This level is minimum height above subtransmission line which magnetic field is within safety criteria for 115 kV subtransmission line.

At 5 meters away, this distance is the nearest which magnetic field is within safety criteria of 115 kV subtransmission line.

At 1.5 meters away, this distance is the nearest which magnetic field is within safety criteria of 115 kV subtransmission line.

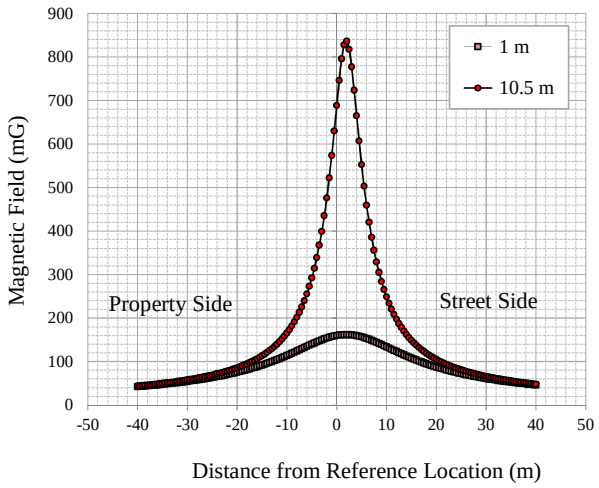

Fig. 23. Magnetic Field at 10.50 meters Height above Ground for 115 kV Subtransmission Line.

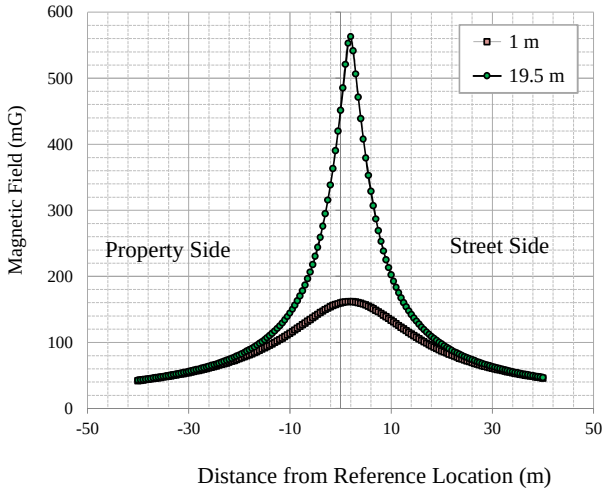

Fig. 24. Magnetic Field at 19.50 meters Height above Ground for 115 kV Subtransmission Line.

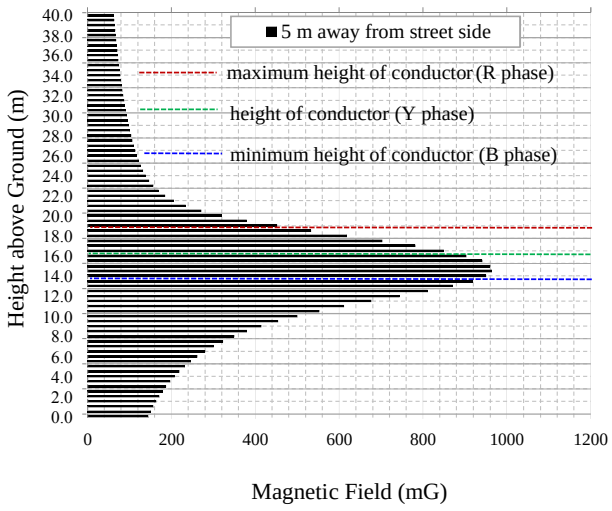

Fig. 25. Magnetic Field at Each Height above Ground Focusing on the Street Side for 115 kV.

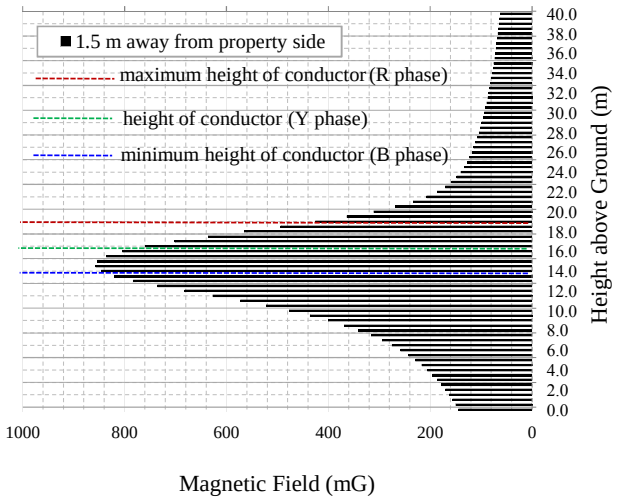

Fig. 26. Magnetic Field at Each Height above Ground Focusing on the Property side for 115 kV.

Magnetic field results of 115 kV within condition and limitation above show that maximum value of magnetic field located at 15.5 meters above ground and 1.5 meters away from property side.

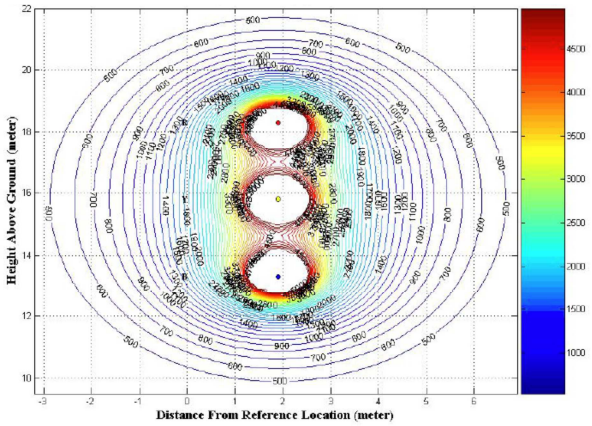

Fig. 27. Magnetic Field Around 115 kV Conductor Carry Out by Matlab Software.

The result of magnetic field around 115 kV can be shown in a graph format. It's plotted by Matlab software as shown in Fig.27.

5. CONCLUSION

This research presents electric and magnetic fields investigation and analysis. Case study information is provided from MEA's 69 and 115 kV subtransmission system by focusing on the conductors' arrangement of the current system. The results show that electric and magnetic fields around the conductors are within safety criteria value of WHO which MEA using as reference. It means those area are safe for human being.

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