DOI: 10.21917/ijct.2021.0376

# A CASE STUDY OF ELECTROMAGNETIC EXPOSURE FOR HIGH TENSION POWER LINES AND TRANSFORMER WITH AND WITHOUT BASE STATION ANTENNA

**Kousik Roy[1], Pratik Dey[2], Naimul Hasan[3] and Susanta Kumar Parui[4]**
[1,2,3]*Department of Electronics and Communication Engineering, Maulana Abul Kalam Azad University of Technology, India*
[4]*Department of Electronics and Tele Communication Engineering, Indian Institute of Engineering Science and Technology, India*

***Abstract***

***With the fast growth of electric activity and the spreading out of town scale, our lives are approached by extremely high voltage power transmission lines. And with the expansion of ultra-high voltage power transmission line, the ultra-high voltage transformer substation will come out in the place with intense inhabitants and the electromagnetic exposure of this transmission and transformer apparatus and its contamination to the inhabitants stimulate the immense anxiety from the civilization. This paper deals with electromagnetic radiation of extremely high voltage power transmission line. Here we have observed the electric and magnetic field beneath the transmission line by the process of equivalent charges and put forward the anticipation rule to the electromagnetic radiation in the engineering of extremely high voltage power dissemination and remodeling. Recognition the safe distance from the EMF produced from the high-tension overhead power lines in the locality of the precise region is the detailed goal of this study. The high-tension transmission lines generated EMF that bounded the projected site has to be underneath 0.2 µT. The safety approval distance has been allotted as 200 m from the active 300-KV high-tension power line.***

***Keywords:***

***High Tension Power Lines, Transformer, Base Station Antenna, Electromagnetic Exposure***

## 1. INTRODUCTION

Electric and magnetic fields, is termed as electromagnetic fields or EMF which can happen physically and as a consequence of the power production, power communication, power sharing and electric power utilization. EMF is the fields of force formed by electric voltage and current and can take place inside electrical devices or on every occasion when power lines are excited. Electric fields are the result of voltage so they are available in electrical devices and cables whenever the electric cable to an electrical device is plugged into an outlet (although the electrical device becomes switched off). Electric fields (E) be present every time a positive or negative electrical charge is there. Other charges within the field are involved forces by this field. An electric field is also produced by any electrical wire that is charged. Although there is no current flowing but still this field exists there. As the voltage is increased, the electric field becomes stronger at any given distance from the wire. The electric field intensity is expressed by volts per meter (V/m} or kilovolts per meter (KV/m}. Substances such as buildings, vehicles and trees can diminish this electric field. Electric fields exposure is eliminated by concealed power lines. If current is flowing throughout the power line or when an electrical device is connected and at switched on condition, then the magnetic fields are produced. Magnetic fields are not generated when an electrical device is connected but not at switched on condition. Throughout the conductor magnetic field lines rushes in circles. As the current becomes higher, the magnetic field strength becomes larger. Magnetic fields are normally expressed by tesla (T) or gauss (G). If the source distance is increased, then the EMF intensity decreases drastically. The electric fields under transmission lines of higher voltage go beyond those underneath the distribution lines of lower voltage. A distribution line of lower voltage with a load of high current possibly creates a magnetic field that becomes as much as those created by some transmission lines of high voltage. Actually, electric distribution systems report for a extreme larger amount of the population exposure to magnetic fields than the larger and more evident high voltage transmission lines. Electrical field is the element of the EMF that can simply be shielded. The EMF element magnetic field can enter into the steel, stone and human flesh. Indeed, when it figures magnetic fields, human flesh and bone has the same absorptivity as air. Both fields are imperceptible and completely quiet. Electric power region located people bordering them some level of artificial EMF. A transmission line creates magnetic field intensity which is proportional to phase to phase spacing, load current, and the inverse square of the distance from the line. Many preceding works studied the effect of different parameters on the created magnetic field such as: the distance from the line, the conductor height, line shielding and transmission line configuration and compaction.

The majority members of the public are not conscious of risks related with mobile phones, high tension power lines and cell tower radiations which are dangerous because of electromagnetic exposure. It is a well-known reality that a magnetic field is formed whenever an electric current flows and that the larger the current, the higher the magnetic field formed [1].

Enormously high-power electromagnetic radiation can origin electric currents well-built adequate to generate sparks when an induced voltage surpasses the breakdown voltage of the adjacent channel for example, air. These sparks can then ignite flammable materials or gasses, perhaps foremost to an explosion. Hazard of electromagnetic radiation Ordinance (HERO) is the common terminology for this. moving or standing near an antenna at the same time as a high-power transmitter is in function can cause rigorous burns as obtainable in microwaves [2], [3].

Electromagnetic radiation is the occurrence that the energy is sent through the source to the space in the way of electromagnetic wave or the energy is transmitted in the space in the way of electromagnetic wave. Electromagnetic radiation sometimes can comprise the electromagnetic induction. But in the environment protection domain, electromagnetic radiation means all the occurrence of the energy transmitted in the space, not only in the way of electromagnetic wave or electromagnetic induction, but also by the way of static electric induction. In the environment protection domain, electromagnetic radiation generally refers to electric field strength, magnetic field intensity and radio annoyance [4]. The extremely high voltage power transmission engineering comprises extremely high voltage overhead power transmission lines and extremely high voltage transformer substation. There once was discussion about whether extremely high voltage overhead transmission lines and extremely high voltage transformer substation produce electromagnetic radiation or not. Now it is confessed that it will. The main theory is the Maxwell's theory about electromagnetic field that the time-variable current can create magnetic field, the time-variable magnetic field can generate electric field, the time variable electric field can make magnetic field and the magnetic field and electric field mutually communicates and the Electromagnetic wave emerges. Because extremely high voltage overhead transmission lines forms voltage grads, there exists work frequency magnetic field and electric field in them. And the same is extremely high voltage transformer substation [5]– [9].

Electromagnetic fields present in our environment are frequently exemplified by their flux density. Magnetic field is expressed in two means, magnetic flux density *B* which is measured by Tesla (*T*), or as magnetic field strength *H* which is measured by Ampere per meter (A/m) [10]-[12]. In case of linear materials these two values are interrelated by the expression:

$$B=\mu H \tag{1}$$

where $\mu$ is the constant of proportionality often termed as magnetic permeability in vacuum or air or in nonmagnetic materials. Human beings are composite electrochemical systems that converse with the environment in the course of electrical pulses. The time-varying EMF exposure outcomes internal electric fields in body currents and energy absorption in tissues that rely on the coupling systems with the concerned frequency. The Power density (*P*) is the rate of flow of electromagnetic energy per unit surface area mentioned in $W/m^2$ or $mW/cm^2$. It can be expressed as:

$$P=E^2/\eta \text{ or } P=\eta H^2 \tag{2}$$

where *E* is the electric field intensity and η is the field resistance taken as 377Ω for free space (in air) [13]. High-tension power lines reckoned as the key basis of electric and magnetic fields. Electromagnetic Radiation (EMR) is the stream of photons through space at speed of light; each photon contains a certain amount of energy, which raises with increasing frequency [14]. This energy spread out as it moves. High voltage transmission lines, distribution lines, high voltage transformers, electric power substations, electrical devices as well as industrial devices are few notable reasons of electromagnetic field exposures of Extremely low frequency (ELF) in the environment [15].

The extent of the electric field depends on the disparity in potential between charge-carrying bodies (conductors) apart from the amount of current flowing through the conductor. On the other hand, a magnetic field is formed by the motion of electric charges in form of electric current, and provides the numbers of charges per second passing through the conductor. The degree of the magnetic field is proportional to the current flowing in a conductor, apart from the voltage present. So, EMF is formed where electricity is produced, conveyed or employed. This comprises electric high tension power lines, transformers, electric sections [16], [17]. All electric streams have an allied electric field and magnetic field. The strength of both electric and magnetic fields reduces with distance from the field source. It is easy to shield or block electric fields than magnetic fields [18]. A study on effects of radiation from cell towers and high-tension power lines on residents of buildings illustrates that people who live close to radiation sources are more prone to the risk [19]. ELF based magnetic fields caused by high voltage elements like transmission lines, transformer centers, substations can create rigorous contacts, mainly for the human health [20]-[22]. This exposure has dramatically increased for thirty decades.

## 2. METHODOLOGY

The intensity of EM field and power density is measured in some parts in the vicinity of high-tension power lines and transformer with and without base station antenna situated at Ramsagar village of West Bengal state in India. Taking into account the standard height of the Indian people the EM field exposure was measured at height 1.5 m by means of a three-axis electromagnetic field meter model KM-195 by KUSAM-MECO® brand. This meter can directly measure the electric field strength and then converts the measurement values to the equivalent magnetic field strength units and power density units by means of the regular far-field formulate for electromagnetic radiation. The meter has an electrical field (*E*) sensor type. The instrument has been calibrated by using equipment which has already been calibrated to standards traceable to national standards on 5th November, 2018. Electric field was measured in mV/m, magnetic field in mA/m and power density in $\mu W/m^2$.

## 3. RESULTS AND DISCUSSION

The results of the Variation in EM radiation of power lines (Coordinates vs. Power Density at different distance) are shown in the Table.1 below. From Table.1, it is seen that power density is increased gradually as we move far away from this power lines and reach its maximum value of 1342 $\mu W/m^2$ at a distance of 60 m from this power lines and after this 60 m distance power density become decreased slowly.

Table.1. Variation in EM radiation of power lines (Coordinates vs. Power Density at different distance)

| **Coordinates (Latitude, Longitude)** | **Distance (m)** | **Power Density ($\mu W/m^2$)** |
|---|---|---|
| N 23°6’50.1948”, E 87°16’40.44” | 10 | 18.06 |
| N 23°6’49.1976”, E 87°16’39.9” | 20 | 52.89 |
| N 23°6’48.3768”, E 87°16’39.6768” | 30 | 97.26 |
| N 23°6’47.736”, E 87°16’39.09” | 40 | 999.8 |
| N 23°6’47.6496”, E 87°16’39.2376” | 50 | 1276.3 |
| N 23°6’44.2296”, E 87°16’37.5096” | 60 | 1342 |
| N 23°6’39.0996”, E 87°16’35.022” | 70 | 1259.8 |
| N 23°6’35.6256”, E 87°16’32.6208” | 80 | 872 |
| N 23°6’32.3676”, E 87°16’30.9288” | 90 | 787.8 |
| N 23°6’29.4156”, E 87°16’29.0028” | 100 | 684.6 |
| N 23°6’27.2268”, E 87°16’27.7536” | 110 | 648.2 |

The results of the variation in EM radiation of power lines (Coordinates vs. Electric Field at different distance) are shown in the Table.2. From Table.2, it is seen that electric field is increased gradually as we move far away from this power lines and reach its maximum value of 899.5 mV/m at a distance of 70 m from this power lines and after this 70 m distance electric field become decreased slowly.

Table.2. Variation in EM radiation of power lines (Coordinates vs. Electric Field at different distance)

| Coordinates (Latitude, Longitude) | Distance (m) | Electric Field (mV/m) |
|---|---|---|
| N 23°6’50.1948”, E 87°16’40.44” | 10 | 105.3 |
| N 23°6’49.1976”, E 87°16’39.9” | 20 | 176.7 |
| N 23°6’48.3768”, E 87°16’39.6768” | 30 | 236.2 |
| N 23°6’47.736”, E 87°16’39.09” | 40 | 716.6 |
| N 23°6’47.6496”, E 87°16’39.2376” | 50 | 824.5 |
| N 23°6’44.2296”, E 87°16’37.5096” | 60 | 833.8 |
| N 23°6’39.0996”, E 87°16’35.022” | 70 | 899.5 |
| N 23°6’35.6256”, E 87°16’32.6208” | 80 | 748 |
| N 23°6’32.3676”, E 87°16’30.9288” | 90 | 710.2 |
| N 23°6’29.4156”, E 87°16’29.0028” | 100 | 664.8 |
| N 23°6’27.2268”, E 87°16’27.7536” | 110 | 648.3 |

The results of the Variation in EM radiation of power lines (Coordinates vs. Magnetic Field at different distance) are shown in the Table.3. From Table.3, it is seen that magnetic field is decreased steadily as we move far away from this power lines. Magnetic field reaches its maximum value of 6.819 mA/m at a distance of 10 m from this power lines and reaches its minimum value of 2.080 mA/m at a distance of 110 m from this power lines.

Table.3. Variation in EM radiation of power lines (Coordinates vs. Magnetic Field at different distance).

| Coordinates (Latitude, Longitude) | Distance (m) | Magnetic Field (mA/m) |
|---|---|---|
| N 23°6’50.1948”, E 87°16’40.44” | 10 | 6.819 |
| N 23°6’49.1976”, E 87°16’39.9” | 20 | 4.261 |
| N 23°6’48.3768”, E 87°16’39.6768” | 30 | 3.375 |
| N 23°6’47.736”, E 87°16’39.09” | 40 | 2.372 |
| N 23°6’47.6496”, E 87°16’39.2376” | 50 | 2.397 |
| N 23°6’44.2296”, E 87°16’37.5096” | 60 | 2.449 |
| N 23°6’39.0996”, E 87°16’35.022” | 70 | 2.179 |
| N 23°6’35.6256”, E 87°16’32.6208” | 80 | 2.102 |
| N 23°6’32.3676”, E 87°16’30.9288” | 90 | 2.095 |
| N 23°6’29.4156”, E 87°16’29.0028” | 100 | 2.083 |
| N 23°6’27.2268”, E 87°16’27.7536” | 110 | 2.080 |

The results of the Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Power Density) are shown in the Table.4. All the readings are taken from 5 m distance from this transformer. From Table.4 it is seen that for this transformer without BTS the highest power density value is 2030 μW/m² and the lowest power density value is 1660.3 μW/m².

Table.4. Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Power Density)

| Coordinates (Latitude, Longitude) | Power Density (μW/m²) |
|---|---|
| N 23°5’55.8528”, E 87°16’21.0468” | 1701.1 |
| N 23°5’55.8564”, E 87°16’21.0504” | 1762.1 |
| N 23°5’55.8492”, E 87°16’21.0432” | 1851.4 |
| N 23°5’55.8456”, E 87°16’21.036” | 1877.6 |
| N 23°5’55.824”, E 87°16’20.9964” | 1784.3 |
| N 23°5’55.8168”, E 87°16’20.9496” | 1660.3 |
| N 23°5’55.7952”, E 87°16’20.9136” | 1861.3 |
| N 23°5’55.7916”, E 87°16’20.91” | 2030 |
| N 23°5’55.7844”, E 87°16’20.9064” | 1825 |
| N 23°5’55.7772”, E 87°16’20.8884” | 1825 |

The results of the Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Electric Field) are shown in the Table.5. All the readings are taken from same 5 m distance from this transformer. From Table.5 and Fig.5 it is seen that for this transformer without BTS the highest electric field value is 1146.3 mV/m and the lowest electric field value is 1028.9 mV/m.

Table.5. Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Electric Field)

| Coordinates (Latitude, Longitude) | Electric Field (mV/m) |
|---|---|
| N 23°5’55.8528”, E 87°16’21.0468” | 1051.7 |
| N 23°5’55.8564”, E 87°16’21.0504” | 1060.8 |
| N 23°5’55.8492”, E 87°16’21.0432” | 1076.9 |
| N 23°5’55.8456”, E 87°16’21.036” | 1082 |
| N 23°5’55.824”, E 87°16’20.9964” | 1067.1 |
| N 23°5’55.8168”, E 87°16’20.9496” | 1028.9 |
| N 23°5’55.7952”, E 87°16’20.9136” | 1100 |
| N 23°5’55.7916”, E 87°16’20.91” | 1146.3 |
| N 23°5’55.7844”, E 87°16’20.9064” | 1084.1 |
| N 23°5’55.7772”, E 87°16’20.8884” | 1088 |

The results of the Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Magnetic Field) are shown in the Table.6. All the readings are taken from same 5 m distance from this transformer. From Table.6 and Fig.6 it is seen that for this transformer without BTS the highest magnetic field value is 2.382 mA/m and the lowest magnetic field value is 2.283 mA/m.

Table.6. Variation in EM radiation of transformer without base transceiver station (BTS) (Coordinates vs. Magnetic Field).

| Coordinates (Latitude, Longitude) | Magnetic Field (mA/m) |
|---|---|
| N 23°5’55.8528”, E 87°16’21.0468” | 2.283 |
| N 23°5’55.8564”, E 87°16’21.0504” | 2.321 |

| | |
|---|---|
| N 23°5’55.8492”, E 87°16’21.0432” | 2.369 |
| N 23°5’55.8456”, E 87°16’21.036” | 2.382 |
| N 23°5’55.824”, E 87°16’20.9964” | 2.328 |
| N 23°5’55.8168”, E 87°16’20.9496” | 2.294 |
| N 23°5’55.7952”, E 87°16’20.9136” | 2.328 |
| N 23°5’55.7916”, E 87°16’20.91” | 2.382 |
| N 23°5’55.7844”, E 87°16’20.9064” | 2.329 |
| N 23°5’55.7772”, E 87°16’20.8884” | 2.321 |

The results of the Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Power Density) are shown in the Table.7. All the readings are taken from 5 m distance from this transformer. From Table.7, it is seen that for this transformer with BTS the highest power density value is 1881.4 μW/m² and the lowest power density value is 751 μW/m².

Table.7. Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Power Density)

| **Coordinates (Latitude, Longitude)** | **Power Density (μW/m²)** |
|---|---|
| N 23°6’10.3536”, E 87°15’54.3888” | 818 |
| N 23°6’3.9096”, E 87°16’4.422” | 751 |
| N 23°6’10.3968”, E 87°15’54.6948” | 992 |
| N 23°6’9.9864”, E 87°15’54.8208” | 1586.2 |
| N 23°6’9.972”, E 87°15’54.8208” | 1721.7 |
| N 23°6’41.8716”, E 87°15’14.0508” | 1684.1 |
| N 23°6’10.71”, E 87°15’53.7984” | 1871.6 |
| N 23°6’10.7316”, E 87°15’53.6688” | 1857.7 |
| N 23°6’41.8716”, E 87°15’14.0508” | 1710.1 |
| N 23°6’11.3616”, E 87°15’54.63” | 1881.4 |

The results of the Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Electric Field) are shown in the Table.8. All the readings are taken from same 5 m distance from this transformer. From Table.8, it is seen that for this transformer with BTS the highest electric field value is 1098.5 mV/m and the lowest electric field value is 678 mV/m.

Table.8. Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Electric Field).

| **Coordinates (Latitude, Longitude)** | **Electric Field (mV/m)** |
|---|---|
| N 23°6’10.3536”, E 87°15’54.3888” | 712 |
| N 23°6’3.9096”, E 87°16’4.422” | 678 |
| N 23°6’10.3968”, E 87°15’54.6948” | 798 |
| N 23°6’9.9864”, E 87°15’54.8208” | 1007.7 |
| N 23°6’9.972”, E 87°15’54.8208” | 1056.5 |
| N 23°6’41.8716”, E 87°15’14.0508” | 1043.2 |
| N 23°6’10.71”, E 87°15’53.7984” | 1098.5 |
| N 23°6’10.7316”, E 87°15’53.6688” | 1091.3 |
| N 23°6’41.8716”, E 87°15’14.0508” | 1054.5 |
| N 23°6’11.3616”, E 87°15’54.63” | 1087.3 |

The results of the Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Magnetic Field) are shown in the Table.9. All the readings are taken from same 5 m distance from this transformer. From Table.9, it is seen that for this transformer with BTS the highest magnetic field value is 2.374 mA/m and the lowest magnetic field value is 2.120 mA/m.

Table.9. Variation in EM radiation of transformer with base transceiver station (BTS) (Coordinates vs. Magnetic Field).

| **Coordinates (Latitude, Longitude)** | **Magnetic Field (mA/m)** |
|---|---|
| N 23°6’10.3536”, E 87°15’54.3888” | 2.132 |
| N 23°6’3.9096”, E 87°16’4.422” | 2.140 |
| N 23°6’10.3968”, E 87°15’54.6948” | 2.120 |
| N 23°6’9.9864”, E 87°15’54.8208” | 2.269 |
| N 23°6’9.972”, E 87°15’54.8208” | 2.292 |
| N 23°6’41.8716”, E 87°15’14.0508” | 2.285 |
| N 23°6’10.71”, E 87°15’53.7984” | 2.341 |
| N 23°6’10.7316”, E 87°15’53.6688” | 2.344 |
| N 23°6’41.8716”, E 87°15’14.0508” | 2.286 |
| N 23°6’11.3616”, E 87°15’54.63” | 2.374 |

The highest electric fields are about 899.5 mV/m, 1146.3 mV/m and 1098.5 mV/m which compare to ICNIRP 2010 value of 10 KV/m for occupational exposure, is about 0.008%, 0.011% and 0.010% of the ICNIRP value.

## 4. CONCLUSION

The result of the study illustrates a high level of conformity of the ICNIRP guidelines as the radiation levels obtained exceed accepted safe level of magnetic field of 0.4 μT and 0.024 W/m$^2$ for power density. If the measured data is compared with that of ICNIRP data then it is found that the highest magnetic field values are below ICNIRP data by about 98%, which means that the 330KV line causes no magnetic field hazard. The maximum electric field values of this 330KV power line are less than ICNIRP data by about 99.5%, indicating no electric field hazard from the power line.

So, we concluded that in case of high-tension power line power density and electric field is increased gradually as we move far away from this power lines and reach its maximum value at a certain distance from this power lines and after this distance power density become decreased slowly. Magnetic field is decreased steadily as we move far away from this power lines. Similarly, in case of a Transformer without nearest Cellular Base Station the EMR exposure level is high compare to a Transformer with nearest Cellular Base Station as the Electromagnetic Radiation (EMR) is repulsion each other in case of Transformer with nearest Cellular Base Station Antenna.

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