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Electric and Magnetic Field Management Methods for Energy Management

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Abstract-Electrical facilities produce power frequency electromagnetic fields. It is reported that those power frequency fields may disturb working of sensitive electronic equipment. Even a human's biological system is reported to be sensitive to these non- ionizing Extremely Low frequency Electromagnetic Fields (ELF EMF). Concerns for technical as well as health effects of ELF EMF around power frequency sources were evaluated in history and they are still continuing. Even after extensive efforts common and uniform option is not drawn technically or clinically. However, professional organizations like EPRI have started their efforts towards field management research. Several research programmes were initiated on long run to identify exact association of power frequency fields with instruments and humans. These programmes have the objective to examine and identify ways to reduce the level of exposure to electric and magnetic fields around the electrical transmission and distribution lines, substations, electrical utilities and electronics devices as well as environmental aspects. In the present work, it has been tried to analyze the various EMF calculations, its effects as well as EMF MGT in various electrical and electronics systems. This article explores all the issues in concern to power frequency ELF EMF management.

Keywords: *Non- ionizing Extremely Low frequency Electromagnetic Fields (ELF EMF), EMF management, EPRI, Graham-Stetzer (GS) meter and GS filters, OHTL, UGTL.*

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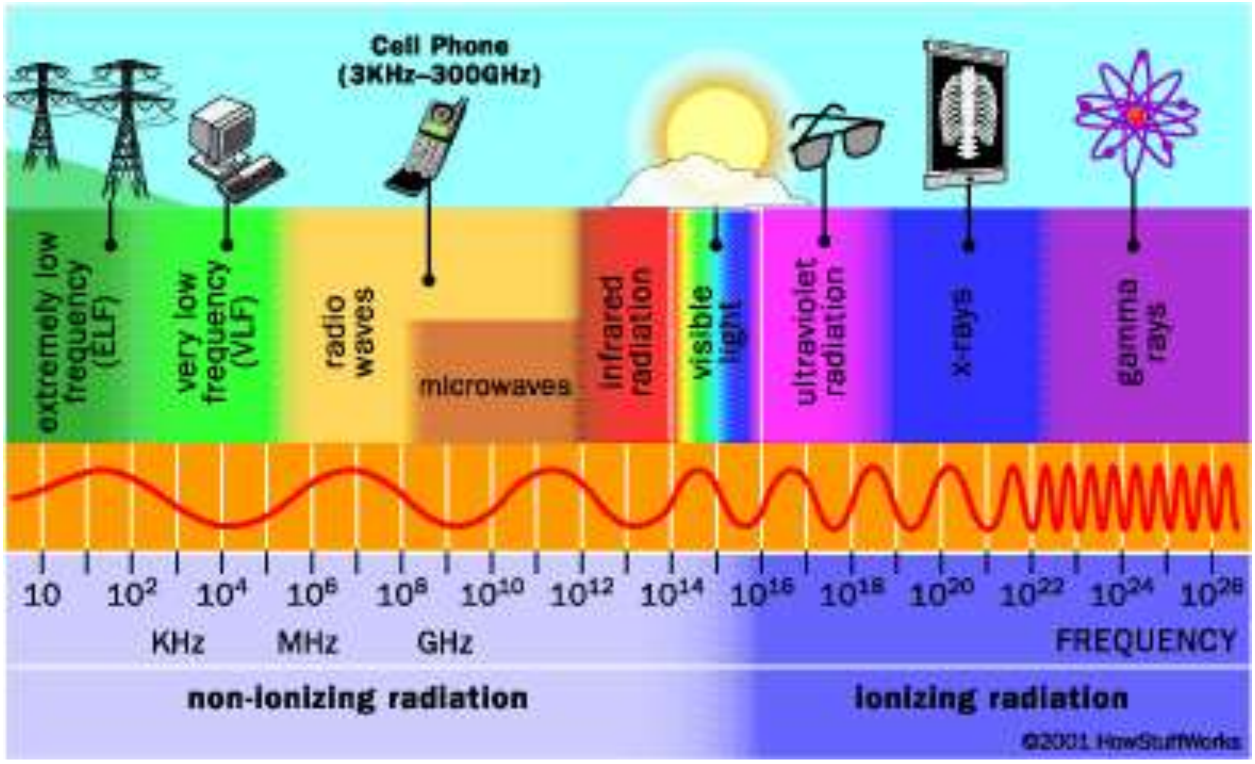
I. INTRODUCTION

Electrical facilities produce power frequency electromagnetic fields. It is reported that those power frequency fields may disturb working of sensitive electronic equipment. Even a human's biological system is reported to be sensitive to these non- ionizing Extremely Low frequency Electromagnetic Fields (ELF EMF). Concerns for technical as well as health effects of ELF EMF around power frequency sources were evaluated in history and they are still continuing. Even after extensive efforts common and uniform option is not drawn technically or clinically. However, professional organizations like EPRI have started their efforts towards field management research. Several research programmes were initiated on long run to identify exact association of power frequency fields with instruments and humans. These programmes have the objective to examine and identify ways to reduce the level of exposure to electric and magnetic fields around the electrical transmission and distribution lines, substations, electrical utilities and electronics devices as well as environmental aspects. EPRI or WHO's research programme provides the common platform to all the efforts concentrated towards effects of ELF EMF. It avoids the duplication of work as well as helps to test and evaluate the most promising ideas in this concern so that they can be adopted technically. According to EPRI, "EMF management" is much more than simply reducing the fields. It may include the variety of activities like communication programs, EMF measurement and assessment, research programs, design of power system components with low EMFs. Modification of power system to reduce EMF, tracking ground and net current flows, shielding the sources of EMF, shielding the areas occupied by people or sensitive equipment and reduction of exposure to EMF by selective use of space and time [1].

II. ELECTROMAGNETIC SPECTRUM

Electric and magnetic fields or EMF are weak, invisible fields of energy that exist around anything that carries or uses electricity. The strength of these fields quickly decreases as you move away from the source.



Dirty Electricity from 2 kHz-150 kHz (transient bursts).

III. EMF MEASUREMENTS & CALCULATIONS

EMFs are generated by generation plants, equipments, T&D lines and cables, and almost all the appliances that work on electric supply. Electric field is produced by voltage, whereas current is the source of magnetic field. Major sources of electric fields are overhead high voltage transmission lines, high voltage equipments in generating stations, overhead distribution lines, special laboratory or industrial equipments and electrical appliances. Magnetic fields are produced by the conductors and buses in generating stations and electrical substations, substation equipments, overhead and underground transmission lines, water lines, water mains when carrying ground currents of the power systems, electrical wiring of residences, commercial and industrial building, computers, electrical appliances and industrial equipments that contains motors and transformers or high current conductors.

The IEEE has set a detailed set up for measurement of electric and magnetic fields.

EMF calculations In the last few decades, concern about the health effects of EMFs has increased rapidly worldwide. Therefore, the main purpose of calculating the electric and magnetic field sources, such as distribution lines, overhead transmission lines, transmission cables, substations, and residential as well as commercial and industrial sector is to minimize the impact of their dangerous effects. The electric field can be calculated can be calculated neat the power line at 1metre above from ground is essentially vertical along the route of the power line. On the other hand, magnetic fields may be calculated 1metre above from ground is essentially both vertical and horizontal components. The various calculations formula can be obtained from the various Maxwell's equations [3] as under:-

(1) Gauss' Law of electrostatics

$$\Psi = \int\int D(r).\, ds = Q = \int\int\int \rho dv$$

$$\nabla . D(r) = \rho_v$$

(2) Gauss' Law of magnetostatics

$$\Psi_m = \int\int B(r).\, ds = 0$$

$$\nabla . B(r) = 0$$

(3) Faraday's Law of Electromagnetic Induction

$$V = - \int E(r).\, dl = -(\delta/\delta t) \int\int B(r).\, ds$$

$$\nabla \times E(r) = \delta B(r)/ \delta t$$

(4) Biot Savart's Law

$$B(r) = (\mu_0 /4\pi)\, I \int_c (dI \times r) /r^2$$

$$\nabla \times H(r) = J + \delta D /\delta t$$

The electric field is determined by the following parameters such as,

- Working voltage of equipment or line.
- Diameter of conductor.
- Number of conductors per bundle.

- Distance between phases.
- Distance of conductors from the ground etc.

IV. HEALTH EFFECTS OF ELECTRICAL POLLUTION

While the term electrical pollution is not a scientific term, there has been a lot of research and case studies done to understand the connection between electromagnetic field radiations and human health. Some are as under:-

- The wire and transformers are not only delivering the juice to run the electrical devices, but are also the carrier of dangerous high frequency currents. The high frequency currents most commonly created by computers and other electronic devices are circulated by various wires and system emitting high frequency currents in homes or office environments. Some of those health problems being attributed to electrical pollution include fibromyalgia, attention deficit disorder, asthma, chronic fatigue syndrome, diabetes, multiple sclerosis and migraine headaches.
- Reduced blood glucose levels.
- Improved diabetes.
- Improved asthma.
- Improved multiple sclerosis.
- Higher PH (reduced acidity).
- Increased headaches frequencies.
- Improved teacher & student well-being.
- Reduced insomnia.
- Higher dirty electricity has been correlated with Increased cancer incidence.
- Experiencing Fatigue.
- Chills
- Fever and dry throat on consistent basis.
- Reduced sleeping.
- Due to some internal factors such as electronic equipment that distorts 50hz power when the dc power has created ac power. A distorted 50Hz wave is a normal 50Hz current polluted by high frequency voltages and currents.

Americans are surrounded by electrical devices, computers, VCRs and a plethora of household gadgets and consumer appliances. There is also an assumption that the electrical and associated electrical phenomenon such as electrical and magnetic fields are safely confined to the wires carrying electricity and to the electrical devices themselves [5].

For a variety of reasons, including the very design of the electrical distribution system, this assumption is no longer valid. Electricity is a trusted component of contemporary civilization. Few notice the poles, wires, substations and transformers that deliver electricity. Yet all contribute to an increasingly dangerous electrical environment that has largely escaped systematic monitoring. The increasing demand for electricity and the proliferation of computers and other electronic devices have marked increased our exposure to electrical phenomenon especially electrical and magnetic fields. These phenomena are a ubiquitous presence in our lives, albeit invisible and odorless. The truth is that the millions of Americans live and work in environments that subject them to a variety of harmful electrical phenomena. One of the most potent contaminants is electrical and magnetic fields in form of radio-frequency radiations.

Radio-frequency radiations: Of particular concern is the high-frequency current created by the computers and other electronic devices, which is often called as dirty current. This current is created by numerous devices and is conducted nearly everywhere. The wiring in the buildings then acts as antennae for the current silently and insidiously assaulting those who play and work nearby. So, the wires that deliver electricity have also become conduits for high frequency radiations, a form of electromagnetic field that has largely escaped attention by the medical community. The increased prevalence of this radio-frequency currents has coincided with an alarming increase in the prevalence of ailments such as fatigue syndrome, disorder, diabetes and asthma. Various symptoms of exposure to radio-frequency radiations (radio wave sickness) had already been seen in the human body such as **Neurological** headaches, dizziness, nausea, difficulty concentrating, memory loss, irritability, depression, anxiety, insomnia fatigue, weakness, muscle spasms, muscle and joint pains, leg/foot pain, altered reflexes, Flu like- fever, seizures, paralysis, stroke and psychosis.

Cardiac palpitations, arrhythmias, pain or pressure in the chest, low or high blood pressure, slow or fast heart rate, shortness of breath.

Respiratory sinusitis, bronchitis, pneumonia, asthma.
Dermatological skin rash, itching, burning, facial, flushing.
Ophthalmologic pain or burning in the eyes, pressure in/behind the eyes, deteriorating vision, floaters, cataracts.
Others digestive problems, abdominal pain, enlarged thyroid, testicular/ovarian pain, dryness of lips, tongue, mouth and eyes, great thirst, dehydration, nosebleeds, internal bleeding, altered sugar metabolism, immune abnormalities, redistribution of metals within the body, hair fall, pain the teeth, deteriorating fillings, impaired sense of smell, ringing in the ears.

A filter and a meter have been created to measure and control the electrical pollution, the filters are inexpensive and have proven to be effective in controlling the harmful high frequency currents from entering homes or offices. The

Graham-Stetzer (GS) meter and GS filters are the most common tools to measure and reduce electrical pollution. The technology used to create the GS meters and filters is based on electromagnetic theories and power engineering principles. The filters provide a low impedance path for high frequency currents from the hot wire(s) to the neutral wire path bypassing the customer loads. Filter frequency ranges from 4 kHz to 100 kHz provide optimal results for cleaning the electricity. Any frequencies above 100 kHz or below 4 kHz are hard to detect by the filters.

Averaging or RMS meters do measure the amount of electricity present, but the GS meters have demonstrated their ability to measure the amount of harmful electricity present. Electrical current enters the body more readily at higher frequencies, and body current at those higher frequencies can be harmful. The GS meter measures currents at those higher frequencies by measuring the sum of the frequencies above 60 Hz.

V. ELECTROMAGNETIC FIELD MANAGEMENT

1. EMF MGT for Transmission Lines Among all the sources of EMF, overhead Transmission lines produced the greatest EMF. Nowadays, extra high voltage (EHV) is transmitted through overhead transmission lines. The installations and distribution of EHV transmission line produce the highest electric field near the ground surface. Overhead transmission lines (OHTL) produces extremely low frequency (ELF) EMF, which requires reducing to minimum level. In the age of electrification, the evaluation of EHV, people are used to stay around ELF field sources, which may further lead to responsible for biological effects of human as well as living beings. Electric and magnetic field management of overhead transmission lines required in different factors of line design and techniques for reduction of EMF have low value. Electric field is reducing to extremely low values using ground grids of densely spaced wires and also it is possible to significantly reduce the magnetic field of lines with voltage upto 115kV or by using loops cancellation method. Underground cabling is the alternative solution to minimize the electric field.

2. EMF MGT for Transmission cables EMF is an issue that concerns overhead transmission lines. Concern about possible health effects due to EMF overhead transmission lines is replaced by underground transmission lines (UGTL) as the solution of EMG problem. In UGTL, above the surface of the ground, the electric field is eliminated, but the magnetic field is not, because the soil around the underground cable has practically the same permeability as air. Thus, near the surface of ground MF from underground transmission line is higher than that of overhead transmission lines.

3. HTSrs in Power cables Leading challenges in power T&D system will be solved by the HTSing technology where HTSing cables are highly capable to wear large JC under cryogenic conditions (77^0K) with zero resistance, low impedance, zero electromagnetic radiation and free from hazardous cooling oil than conventional power cables and wires. Underground AC/DC power T&D network of HTSrs use inexpensive and environmentally safe LN_2 cooling core which provides cooling to the material to maintain the superconducting state. In addition, the installation cost of underground and overhead power cables can be reduced more than 20%. In conventional overhead Cu based power T&D cable system, about 50kW/km of electrical energy is dissipated due to high resistance of conductor can be reduced by HTSrs (table 1) [7]. For transportation of 5GW power with 75kV overhead AC lines require 600’ wide ROW and 130’ high pole & whereas 5KW with 200kV underground DC HTSrs cable require about 3’ diameter pipe and 25’ROW according to AMSC (USA).

Table 1: Comparison of HTSing and conventional cables

Sr. No.	Description of cable specifications	Conventional conductors AC cables	HTSing AC cables	HTSing DC cables
1.	Power transmission capacity (MVA)	1500	1500	1500
2.	Power transmission voltage	275kV rms	66V rms	130kV
3.	Power transmission current	1kA rms/phase	3.3 kA rms/phase	12kA/phase
4.	Cable type and diameter size (cm)	Single phase XLPE (14cm)	3 in one (13.5cm)	3 in one (13.5cm)
5.	No. of cables	9	4	1
6.	Transmission cables (kW/km)	740	200	20
7.	CO2 emission and rediction	778	210,562	21,757

High superconducting cable, characterized by high current densities and low transmission loss, shows promise as a compact low-capacity power cable that exhibits several environmental advantages such as energy and resource conservation as well as no external electromagnetic fields. HTS DC cable takes maximum advantage of the characteristics of superconductivity. Because they are absent of those problems unique to AC applications, HTS DC cables are expected to outspace HTS AC cables, in line with future performance enhancements and price reduction of converters.

HTS DC cable is a large-capacity, compact, energy-saving & environmentally-friendly cable. Moreover, further improvements in performance & declines in price are likely to give rise to greater economic efficiency. High-temperature superconducting (HTS) cable, characterized by high current density and low transmission loss, shows promise as a compact large-capacity power cable that exhibits several environmental advantages such as energy and resource conservations as well as no external electromagnetic fields, nonexplosiveness, non-flammability and non-toxicity. Due to these advantages, HTS AC cable demonstration projects are being planned and promoted. The zero resistance of HTS material is observed only in DC current, while the transmission loss is generated in AC current. Moreover, it is necessary to take measures to solve the problems to HTS AC cables such as protection against short circuit current and solution to avoid unbalanced AC current in each HTS conductor. HTS DC cable, on the other hand, is a cable that utilizes the advantages of superconductivity most effectively and shows no problem inherent in HTS AC cables.

Basic Structure of HTS DC cables (EMI free) In HTS AC cables, superconducting wires are used for shielding with both ends shorted. In this manner, the current in the reverse phase form the conducting current flow can be induced to carry through the superconducting shielding layer. This induction cancels the magnetic field outside the shielding layer to create a state that is purely free of electromagnetic interference, which means that no leakage of any electric field is allowed. An EMI-free state can also be created in HTS DC cable by flowing the return current through the shielding layer in monopolar transmissions and by carrying the positive and negative currents side by side in bipolar transmissions.

HTS DC cable applications: In view of the above advantages and superiority of HTS DC cable, the major applications can be as under:-

1. Ultra-high substations.
2. Primary substations.
3. Relay substations.
4. Distribution substations.
5. From back-to-back to interconnection applications and other applications.

4. Distribution Lines EMG MGT Overhead distribution lines generate an electric field around the line that influences the human being and the nearby objects located at ground surfaces. Normally, distribution lines electric field are so small that they do not produce any effects like spark discharge. But in case of magnetic field management or reducing the magnetic field produced by the distribution system created two special challenges. First one is associated with the large societal cost of an overall change in distribution system. The second one is related to the different techniques that are required to reduce the magnetic field caused by phase and net current in the distribution system.

5. EMF Management in Substation Substation is a key component of electrification of any region for smooth operation and reliability of transmission and distribution system. The substation having mainly major components as transmission lines, step-up/ step-down transformers, substation buses, sub-transmission feeders and generating circuits.

The EMF produced by substations may expand outside the substation perimeter, where residential and commercial activity takes place. Management of EMF near the substation is very complex issues. Sources of Electrical field in the substation are the substation buses and HV equipments. Electric field can be controlled by design of buses and their geometry and alos be reduced by increasing the space between ground and buses.

On the other hand, sources of magnetic field around the substation are substation buses, incoming and outgoing cables, capacitor banks etc. Management of MF around a substation has mainly two purposes: the first is associated with the field level inside the substation to ensure the safety of workers, and second one is to minimize the MF outside the perimeter of substation where residential and commercial settlements are found. This can also be required to modeling of conductors and buses.

6. Residential EMF management EMF is also produced near the residential area due ot HV transmission line cross over in case of urban areas. People spent most of time in their homes, over the contact of EMF issues. Electric field in the home is relatively small and insignificant as compared to magnetic field. Sources of magnetic fields in residential areas are as follows:-

- Grounding System of the residence.
- Overhead power distribution line.
- Electrical appliances.
- Computers
- Electronics devices.
- Unsuitable Electrical wiring.
- Overhead power transmission lines.
- Ground connections at electrical subpanels.

Most of the magnetic fields generate in the residential area due to electrical appliances such as electrical heater, air-conditioning, computer etc. placed in the residential environment. It has been a concern because a number of epidemiological studies have indicated to some dangerous diseases- such as leukemia, breast cancer, miscarriage etc.

7. School, commercial and Industrial EMF management Electrical and magnetic fields are not only produced in generation and transmission systems but they are also produced in the distribution system. The main purpose of management of electric and magnetic fields in schools, colleges, commercial and industrial premises is lowering the exposure to EMF. Sources of MF in industrial areas are mainly the electrical machinery and equipment that are used in electrical transmission and distribution systems. According to survey of EPRI, the magnetic field sources in school, colleges, commercial are given below:-

Sources in School, Colleges

- Net currents in electrical wiring.
- Fluorescent lights.
- Electrical typewriters, computer, printers etc.
- Air conditioning and room heaters.
- Aquariums.

Sources in Offices

- Net currents in electrical wiring.
- Fluorescent lights.
- Current in cables
- Air conditioning and room heaters.
- Computer, printers etc.
- Switches and relays in electrical distribution.

EMF values in the industrial areas are higher than the residential and commercial areas. So, need for management of their EMFs is very important. Their harmful effects include breaking of the bones and tissues.

VI. CONCLUSION

The main conclusions submitted are as under:-

- Exact association of power frequency fields with instruments and humans is still being evaluated and efforts are going on worldwide.
- There are various health concerns associated with Electromagnetic emissions experienced by various personnel and obtained the significant effect of EMF radiations on various parts on human body and remedy methods are to be obtained by use of GS filter.

  Electric and magnetic fields around transmission and distribution lines, substations and other electrical HV equipments/ utilities can be reduced by various technical approaches.
- Communication programmes, EMF measurement and assessment, research programmes, design of power system components with low EMFs and use of High Temperature superconducting equipments, modification of power system to reduce EMF, tracking ground and net current flows, shielding the sources of EMF, shielding the areas occupied by people or sensitive equipment and reduction of exposure to EMF by selective use of space and time are the steps that are used for EMF management.

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