IOT-BASED MONITORING SYSTEM FOR HVTL AND ENVIRONMENTAL PREDICTION OF EMR EFFECT

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Background of the research

The impact of the electromagnetic field or radiation on the well-being of biotic and abiotic organisms (including the human population and the environment) that are exposed to this radiation is still a critical issue that has continued to attract public attention for several years. Intensive research works are being conducted all over the world into the effects of electromagnetic radiations on humans and the environment to mitigate the adverse effects of these radiations which do exist and is dependent on field strength, frequency, and exposure (Vladimir et al., 2020). The development of different technologies has expanded the use of a large number of devices and a system whose operation is based on the use of electromagnetic fields such that the density and frequency of radiation in the space in which life exists are multiplied. Consequently, the biotic and abiotic environment is exposed to far higher doses of radiation than was the case with natural sources, which has thus created serious problems for man and the environment (Mahajan and Singh, 2012).

The use of overhead high voltage transmission lines (HVTL) has increased tremendously due to increasing demand to satisfy the need for electricity across communities. The HVTL produces electric and magnetic fields, which combine to give electromagnetic radiation. The radiations produced by the HVTL impact the human body as well as the environment in a negative way. The long-term exposure to electromagnetic fields (EMF) emitted by HVTL leads to the possibility of the residents living within the vicinity to experience health-related issues over a long period without being aware of them.

Electromagnetic radiation (EMR) is composed of sine-shaped waves that propagate through space at the speed of light (approximately 300,000km/s2), characterized by electrical and magnetic fields that are arranged perpendicularly to each other (Lillesand et al, 2004). It is this energy that is transmitted at the speed of light through an oscillating electric and magnetic field. The central property of EMR is the wavelength, inversely proportional to frequency. It ranges from high-frequency gamma rays to radio waves many kilometres long with low frequencies collectively known as the electromagnetic spectrum (EMS). EMR forms the basis for remote sensing (RS), which has gained great relevance in studying and monitoring hazards (Tralli et al, 2005). Remote sensing (RS) has a passive and active methodology. To detect or monitor phenomena related to hazards, a careful selection of the appropriate part of the EMS is critical. Most earth observation instruments such as regular cameras, passively record EMR in the visible part of the spectrum and the adjacent near-infrared. This is ideal to detect the state of vegetation, as the cell structure of healthy green leaves strongly reflects near-infrared (NIR) energy, which declines in stressed leaves. Vegetation stress, possibly leading to crop failure can thus be detected early. EMR is also the basis for other tools in hazard works. It can constitute hazards to living organisms.

The human environment comprises various sources of ionizing and non-ionizing radiation. These include power lines, cable and satellite communications, power stations, electric vehicles (electric trains, trams, and trolleybuses), TV, radio repeaters, etc. As a result, there is an interaction between the electromagnetic fields and biological tissue (human and plant). The effects of these fields can be harmful to humans if the field strength exceeds certain threshold values, which are defined by the corresponding regulations and it is defined based on harmful effects (Kemal et al, 2019). In order to analyse the biological effects of electromagnetic radiation and take inventory of the associated hazards in a particular situation, it is necessary to evaluate the strength of the field in the frequency domain. The same has to be compared with the corresponding allowed value. The field strength values can be determined by applying analytical calculations, numerical methods, or by using the appropriate measurement equipment. Although the non-ionizing electromagnetic phenomena have been well studied, interactions between electromagnetic fields and organic matter, and especially, the human body are still not fully explored (International Commission on Non-Ionizing Radiation Protection Guidelines, 1998; Kerral et al, 2012).

For the transmission and distribution of electric power, networks of High-Voltage Transmission Lines (HVTL) are geographically situated in towns, cities, and remote places across Nigerian terrains. This is evident by the fact that Nigeria's transmission network spans over 11000km (over 5000km of 330 kV transmission lines and 6000km of 132KV transmission lines). It also has roughly 24000km of 33 kV sub-transmission lines and 19000km of 11KV distribution lines throughout the country, as well as 22,500 substations (Ukhurebor et al, 2017). Electromagnetic Fields (EMF), also known as Electromagnetic Radiation (EMR), are produced by these HVTLs and are made up of electric and magnetic fields that propagate orthogonally in the direction of travel. It is worth noting that EMRs are produced not just by HVTLs, but also by other communication equipment such as GSM, radio, and TV masts (Oisamoje et al, 2021).

Time-varying electromagnetic fields are usually generated by time-varying AC (alternating current) electricity during transmission, distribution, and use of electricity. The main sources of time-varying electric fields in the work area are electric cables. The strength of these fields is in the range of 1 to 100 V/m. The flow of electrical current through a conductor produces a magnetic field which often forms a closed loop around the conductor which form them. The frequency of a VLF field depends on the field sources. Radiations consist of both electric and magnetic fields. They are coming from natural and man-made resources. Ionization radiation can cause changes in the structure of atoms or molecules thereby causing damage to living atoms/molecules with the tendency to cause changes in the structure of DNA in the living.

People who live near HVTLs are oblivious of the health risks posed by radiation from high voltage transmission and the distribution networks as stated by some researchers. Protracted health effects have been recorded because of varying degrees of human exposure. Environmental impact is partly related to changes in plants and animal habitats.

The IoT is a recent advance in technology, which integrates the interconnectedness of different systems by adding sensors to them thereby initiating a level of digital intelligence to devices that would have been otherwise dumb, enabling them to communicate real-time data without the direct involvement of a human phase (Al-Khriesat and Al-Odienat, 2020). One of the most critical areas where this technology “IOT” has been deemed very relevant is the High-Voltage Transmission Lines (HVTL) owing to hazards associated with human interfacing.

Though arrays of IoT models such as broadband power line communication (BPLC), wireless self-organized sensor network (WSN), optical fibre composite overhead ground wire (OPGW), general packet radio service (GPRS), and the Beidou (COMPASS) navigation satellite system (CNSS) have been deployed in the power sector (Shao-lei et al, 2012). There is still a paucity of IoT models and data that can directly relate to the impact of EMR on the environment as most of the developed models are concerned with monitoring mechanical faults, structural wellbeing of grids, and scheduling predictive maintenance.

Owing to the harmful effect of the EMR from the HVTL, direct monitoring and evaluation may be very difficult. The Internet of Things (IoT), which combines remote sensing and artificial intelligence analytic capabilities to create a smart grid network, is useful for monitoring the HVTL (Mohammed and Hagem, 2020) and forecasting the status and impacts of EMR on the environment.

Statement of the Problem

High voltage Transmission lines are known to generate large amounts of Electromagnetic radiation (EMR), which has dangerous effects on the environment. Continuous Monitoring of EMR by humans is difficult because of its health implications and there has not been any known remote monitoring of EMR systems using IoT.

Aim and Specific objectives of the Research Project

The Research Project aims at developing an Internet of Things (IoT) Based Electromagnetic Radiation Monitoring System for High Voltage Transmission Power lines.

Specific Objectives

1. To investigate the impact of the EMR emissions from the 330kv and 132kv Transmission lines on humans, plants, and animals.

2. To design an IoT-based monitoring system for 330kv and 132kv Transmission lines.

3. To estimate the extent to which Electromagnetic Radiation (EMR) affects human lives.

4. To implement and deploy the designed model for Electromagnetic Radiation Monitoring.

5. Conduct the performance analysis of the deployed model.

6. Develop a Big data security mechanism for the EMR and climatic data.

Literature Review

It has been established that electromagnetic emission (EME) or electromagnetic radiation (EMR) is vastly distributed via void spaces or over a medium or media like gamma-ray, visible light, radio waves, and electromagnetic waves (SAGE, 2007; Ukhurebor et al. 2017). This can either be produced by man-made or natural means.

Globally, the quest for electrical power has led to the development of high voltage transmission lines (HVTL) because of the population rise and the need for the demand for renewable energy to meet the teeming geometrical population growth (Devine-Wright and Batel, 2013; Ushie et al 2017; Ukhurebor et al., 2019). More so, electromagnetic fields (EMF), also known as EMR, are produced by HVTL and are made up of electric and magnetic fields that propagate orthogonally in the direction of travel. It is worth noting that EMRs are produced not just by HVTL but also by other communication equipment such as GSM, radio, and TV masts (Oisamoje et al. 2020).

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People who live near HVTL are oblivious to the probable health and environmental risks posed by radiation from high voltage transmission and the distribution networks, as stated by some researchers. Protracted health effects like cancer, neurological disorders, leukaemia, headaches, and tiredness have been recorded because of varying degrees of human exposure (Ahlbom et al. 2000; Porsius et al. 2014). Environmental impact is partly related to changes in plants and animal habitats.

Plants' growth and development are influenced by electromagnetic frequencies (EMF). Physiological and morphological changes, increased micronuclei formation, changed growth, and unfavourable cell features like thinner cell walls and smaller mitochondria have all been discovered in studies on wireless EMF. Biochemical alterations are caused by EMR. According to studies, plants are a good model for studying the biological effects of exposure because they perceive and respond to electromagnetic fields. According to a report on documentation of tree damage from base stations titled "Tree Damage Caused by Mobile Phone Base Stations", radio frequency (RF) radiation effects on plants have not been considered. The exploding development of varied wireless communication technologies over the entire environment represents an unforeseen risk (Breunig, 2017).

Phone masts have been installed all over the world in the last few decades, and scientists have debated the potential environmental impact of mobile phone base stations for many years

(Waldmann-Selsam et al., 2016). According to Waldmann-Selsam et al. (2016), there is a possible link between RF radiation and exceptional (usually unilateral) plant damage. The statistical analysis demonstrated in the study shows that EMR from mobile phone masts is harmful to plants. These findings conform with the notion that plant damage caused by mobile phone towers typically begins on one side of the plant and spreads to the entire tree over time (Pall, 2016; Halgamuge, 2017). The rising use of mobile phones and wireless networks has sparked a heated debate concerning the true carcinogenic risk of RF-EMF exposure from these gadgets. According to Gustavino et al. (2016), the bulk of in vivo and in vitro investigations on the ability of RF-EMF exposure to generate DNA damage and mutations in mammalian systems have found inconsistent results. To see if plant systems have less ambiguous responses to RF-EMF exposure than mammalian systems, the mutagenic effect of RF-EMF was investigated using the micronucleus test in secondary roots of Vicia faba seedlings exposed to mobile phone transmission in controlled conditions inside a transverse electromagnetic cell.

Balmori (2021), in a recent review, found sufficient evidence of the harm caused by EMR to insects to conclude that EMR should be seriously considered as a complementary driver for the dramatic decline in insects, acting in concert with agricultural intensification, pesticides, invasive species, and climate change. Suggestively, the review concluded that before any new deployment, the precautionary principle should be implemented. In addition to pesticides and habitat loss, HVTL, mobile communications, and WLAN concluded that mobile communications radiation has negative effects on insects and is thus another factor in the insect world's weakening.

Also, a recent study by Levitt et al. (2021a-b) found that there were exponential increases in nearly all environments; the biological effects have been seen broadly across all taxa and frequencies at vanishingly low intensities comparable to today’s ambient exposures. Broad wildlife effects have been seen on orientation and migration, food-finding, reproduction, mating, nest and den building, territorial maintenance and defence, and longevity and survivorship. Cyto- and genotoxic effects have been observed. It is time to recognize ambient EMF as a novel form of pollution and develop rules at regulatory agencies that designate air as a "habitat" so EMF can be regulated like other pollutants. Wildlife loss is often unseen and undocumented until tipping points are reached. Long-term chronic low-level EMF exposure standards, which do not now exist, should be set accordingly for wildlife, and environmental laws should be strictly enforced.

According to several literature reviews, non-ionizing EMFs are described as a "developing concern" to plants, animals and the environment, and pollinator consequences have also been reported in several published studies. Years of exposure to the cell tower and HVTL radiation have been found to harm plants, animals and the environment. Invertebrates (including insects), birds, and mammals have been found to be affected by RF-EMF. Furthermore, research suggests that the higher frequencies could have a negative influence on bees and pollinators, as the higher frequencies resonate with their bodies, resulting in exceptionally high absorbed power (Levitt et al., 2021a-b).

It is evident from the data obtained from a substantial number of studies that RF-EMF has physiological and/or morphological effects on plants, and these effects could cause poor crop yields and possibly lead to food insecurity, which will invariably affect other living organisms and the ecosystem at large (Halgamuge and Davis, 2019). Due to the harmful effect of the EMR from RF-EMF such as the HVTL, direct monitoring and evaluation may be very difficult (Mohammed and Hagem, 2020).

To the best of our knowledge, there is currently no funded research program into the non-thermal, biological, and environmental effects of RF emissions from EMR such as the HVTL on the plants, animals and the environment in Nigeria. Hence, the Internet of Things (IoT), which combines remote sensing and artificial intelligence analytic capabilities to create a smart grid network, will be useful for monitoring the HVTL and forecasting the status and impacts of EMR on plants, animals and the environment. Continuous monitoring of EMR by humans is difficult because of its health implications, and there has not been any known remote monitoring of EMR systems using IoT. The proposition of a smart grid system; IoT in the monitoring of the effects and distribution of HVTL energies in the Nigerian power system could serve as a device that will efficiently improve the operation and production of electrical power in Nigeria. This will help in the real-time data collection of some climatic parameters influencing its potential, the smart sensing of hazardous emissions, and the prediction of possible negative health and environmental influences using co-joining models to stabilize and optimize the effectiveness of the IoT intelligence gathering

Conceptual framework of the study

EMF is best described by Maxwell's equation, which is based on the experimental laws. Four equations generally governing EMF laws are given as:

$\nabla . \overrightarrow{D} = \rho$ - Electric field from charge distribution: *Gauss' Law*

$\nabla . \vec{B} = 0$ - No Magnetic monopoles, a consequence of Gauss' law in magneto-static form.

$\nabla X \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ - Time-varying magnetic field induces an Electric field: a consequence of Faraday's law of Electromagnetic induction.

$\nabla X \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$ - Current, Time-varying Electric Fields: Maxwell addition with displacement current.

The human body has a Specific Absorption Rate (SAR) owing to varied electric field intensity inside the body. The area with the maximum field has a maximum SAR value owing to density and conductivity variation. The skin depth offers a suitable estimate for EMF penetration in human tissue determined by the frequency *f*, permeability μ, conductivity, σ, and defines how much area of the body is affected by the EMF radiation given by:

$$d = \left(\frac{2}{\omega\mu\sigma}\right)^{1/2} = \frac{1}{\sqrt{\mu f \mu\sigma}} \, (m)$$

d is distance, $\omega = 2\pi f$ is the angular frequency.

Research Methodology

It is worthy of note to state that the methodology for this research work is in two dimensions. The first part which comprise of the health impact of EMR from HVTL and the second part would address the design of IoTs for effective monitoring.

Methodology 1:

Sampling

Composite samples of selected plants, animals, and soil will be collected within the locations of study under HPLs (high power lines). Similarly, samples will be collected from other locations about 1 km from the HPLs which will stand as the reference or control samples. The sampling sites will be marked with triangular pegs with names on them for proper identification. At each site, a GIS machine will be used to get the information about the locations.

Chemical examination

The plants, animals, and soil samples will be wrapped and preserved in Al (aluminum foil) and transferred to the laboratory for PCBs (Polychlorinated Bi-phenyls) evaluation using the standard set by CEN, (2006) and O'berg and Petola, (2009). About 1-2 g wet weight of the samples will be measured after then n-hexane will be used for the extraction of the biological components in the form of a solvent for eight (8) mins and heat-up for 2 cycles for another 5 mins. About 12 congers of the PCBs will be extracted following this process for the plants, animals, and soil samples.

Data evaluation

The PCA (Principal Component Analysis) will be used to detect the source apportionment of possible environmental impact with the aid of SPSS 23.0 software. ANOVA (Analysis of Variance) will be used to determine the differences in the mean values and sites of significant impact using the Microsoft Excel 2023 edition.

Models/Indices

This study will apply the ILCR (incremental life cancer risk assessment) models to assess the possible health risk PCBs emitted from High Power Voltage Lines (HPVLs) portend to human health. Several routes like inhalation, ingestion and contact by dermal means will be examined using the model below by Zhang et al. (2007) and Enuneku et al. (2021).

$$ILCRing=(Csoil \times IngR \times EF \times ED \times CF \times SFO)/(BW \times AT) \quad (1)$$

$$ILCRderm=(Csoil \times SA \times AFsoil \times ABS \times EF \times ED \times CF \times SFO \times GIABS)/(BW \times AT) \quad (2)$$

$$ILCRinh=(Csoil \times InhR \times EF \times ET \times ED \times IUR)/(PET \times AT)^{*} \quad (3)$$

Where ILCRinh, ILCRderm, and ILCRing means inhalation, contact by dermal, and ingestion pathways of PCBs in the selected plants, animals, and soil in mg kg^{-1} respectively. Meanwhile, IngR, EF, ED, CF, SFO, BW, AT, SA, and AF, represent the rate of ingestion (100 mg d^{-1}) for an adult, the frequency of exposure for 350 days/year exempting the 15day yearly holidays, the duration of exposure by assumption 52 years for an ALE (average life expectancy) of an individual in a developing environment, this is the conversion factor which is expressed as 1×10^{-6}, this is the slope factor for the oral/ingestion pathway in 2.0 mg kg^{-1} d^{-1}, this represents the mean body weight for an adult-65 kg, it is the mean carcinogenic days valued as

52×365=25,550 days, this stands for the superficial region of the skin via dermal contact predictable in 3300 cm2, and this represents the factor of adherence of the skin to the samples collected in 0.2 mg cm−2. Meanwhile, GIABS and ABS show the absorption factor for the dermal pathway as 0.1. While the rate of the inhalation-InhR is valued in adults as 15.8 m3d−1 and the absorption factor for the gastrointestinal. The IUR, PET, and ET show the time of exposure and factor of emission as 8 h d−1 and 1.36×109m3 kg−1 for the dermal respectively, and 1.36×109 m3kg−1 and 5.7×10−1 µgm−3 as the unit risk for inhalation (US EPA, 2001, 2009 and 2010; Aganbia et al. 2019).

This study adopted the status for carcinogenic risk as very high (≥10−1), high (10−3 to ≤10−1), moderate (≤10−3), low (10−6 to ≤10−4), and very low (≤ 10−6) (ATSDR, 1995).

Methodology 2:

A survey using a questionnaire for data collection, to be analyzed using a statistical approach.

An IoT-based EMR monitoring and estimation device would be designed based on the conceptual framework illustrated in the block diagram given in figure 1 below. A prototype of the designed system would be actualized using locally sourced materials.

The system would consist of an input interface made of a Radio Frequency Antenna that would be responsible for detecting the EMR waves. The antenna would be coupled to a Demodulating Logarithmic Amplifier (DLA). The DLA would convert the RF signal into equivalent decibel scaled output voltage at a frequency range of 1MHz and 8 GHz, which in turn would be converted to its digital equivalent using an Analog-to-digital converter (ADC).

The ADC is interfaced to the microcontroller such as the Raspberry pi 3, which is named an Edge computing unit, where initial computation would be performed to scale the converted values into equivalent EMR values.

The EMR data would be accumulated in local storage where running averaging technique would be used to clean up the data to ensure it was noise-free. The pre-processed data would then be transmitted to a remote cloud or any other local destination known as RPU for intensive data analytic processing using a Deep learning algorithm such as Long Short-Term Memory (LSTM) for time series prediction of EMR and its corresponding effects.

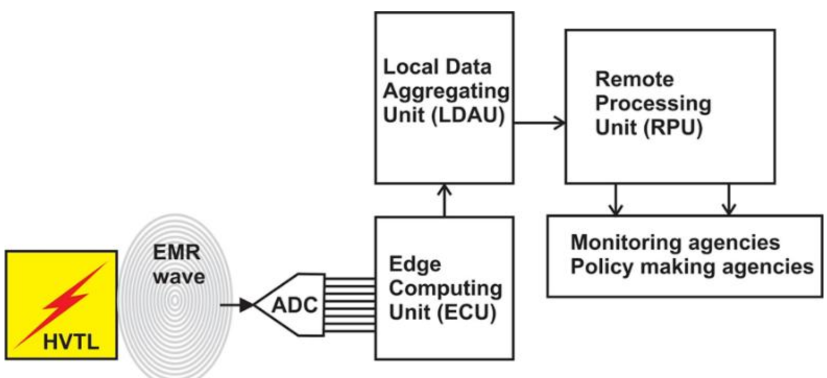

Figure 1: Block diagram of the proposed system

The LDAU would be integrated into the RPU cloud repository using the Message Telemetry Transport (MQTT) and Long-Range Wide Area Network (LoraWAN) protocols and network d

evices. This is the unit that is responsible for performing computations aimed at predicting the effect of EMR on humans and the environment.

Research Outputs and Outcomes

The immediate results/outputs of the proposed research:

1. The accessibility of an IOTs-based EMR monitoring system that could be used in the evaluation of possible radiation emitted from High Voltage Transmission lines in that environment.

2. Prediction of possible health and environmental influences of EMR in other to establish a background level of exposure routes to humans using the proposed models.

3. Repository of meteorological data of the study region to establish the influence of some climatic factors on the frequency of the EMR emission.

The anticipated outcomes are:

1. The development of IoT Based Electromagnetic Radiation Monitoring System for High Voltage Transmission Power lines.

2. The establishment of an EMR and climatic database for the transmission body of the country.

3. The development of health and environmental risk models for the monitoring of PCBs emitted from High Voltage Transmission lines.

Research Impact

The long-term impacts of the research are:

1. In the area of power transmission, this research will ensure adequate data capturing that could be used by the electricity distribution and regulatory companies, research institutes, universities to abstract information for future use.

2. The IOTs device that will be developed will be used to generate funds and stimulate the socio-economic wellbeing of the people of that country.

3. Advancement of the technology and knowledge base in the power sector using the IOTs devices and health and environmental risk models.

4. This research will impact positively in the long run via the production of background information on the monitoring of the effects of radiation from high power voltage lines

5. Providing optimum operational standards for regulators in safety and hazards to personnel during operations and maintenance

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