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Overview of Impact of Electromagnetic Phenomena and Power Quality Disturbances

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ABSTRACT

The usage of increasingly sophisticated electrical and electronic device systems in households and businesses has resulted in a constant rise in the demand for electrical energy. From radar and space exploration at ultra-high frequencies to metal detection at ultra-low frequencies, the electromagnetic spectrum is being used. Technology has advanced to more effectively capture and distribute electrical energy as a result of this need. Because of this, scientists are always looking for novel approaches to maximize the electromagnetic spectrum's utility for a range of purposes. Biological impacts, interactions with sensitive electronic equipment, and the influence of electromagnetic fields on the distribution of electric currents in power circuits are the three main categories into which electromagnetic disturbances can be classified. Due to its increased sensitivity to various electromagnetic phenomena, equipment in residential, commercial, and industrial settings needs immunity. In contemporary power distribution networks, harmonic disturbances are the main factor contributing to power quality degradation in nonlinear loads that contain power electronics. Harmonic disturbances, which can interfere with the operation of delicate electronic equipment, have increased as a result of the widespread use of power electronics in gadgets. Electrical systems must be built with immunity to electromagnetic disturbances to provide consistent power quality. The study highlights the importance of implementing proper grounding techniques and filtering devices to minimize the effects of electromagnetic interference on sensitive equipment. By addressing these issues, power quality can be improved, leading to more reliable operation of electrical systems.

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1. Introduction:

There has been an ever-increasing demand for electrical energy every day. More complex electrical and electronic device systems are being used in homes and industrial areas and introduced into every facet of human endeavor due to the steady improvement in technology [1]. Technological advancements leading to digital equipment and the demand for and use of electromagnetic devices are thus increasing with the daily advent of new wireless devices and applications that require the radio spectrum [2] [3]. Services that utilize the radio frequency spectrum range from broadcasting, telecommunication, and non-telecommunication sectors [4]. Table 1 illustrates the rise in the usage of electronic and electrical devices as well as transmissions used for broadcasting and telecommunication in the electromagnetic spectrum. From radar and space exploration at ultra-high frequencies to metal detection at ultra-low frequencies, the electromagnetic spectrum is being used. Because radars create pulsed microwave signals, they can be utilized for a wide range of purposes, including navigation, weather forecasting, and military applications [5].

Table 1: Frequency Spectrum

Classification	Range	Applications
ELF	3-30 Hz	Detection of buried objects
SLF	30-300 Hz	Electrical power system, Commercial with submarines,
ULF	300-3000 Hz	Telephone audio range
VLF	3-30 kHz	Navigation, Sonar
LF	30-300 kHz	Radio beacon, Navigation
MF	300-3000 kHz	Maritime radio, AM
HF	3-30 MHz	Citizen's band, short wave radio,
VHF	30-300 MHz	FM. Police, Television, Mobile
UHF	300-3000 MHz	television, radar, navigation
SHF	3-30 GHz	satellite and radar,
EHF	30-300 GHz	space exploration and radar

However, it goes without saying that the advancement in technology is not without challenges as it is posing subtle threat to the environments both in terms of human health and products lifespan. In general, there are two categories into which electromagnetic disturbances can be classified: i) Living things and ii) Non-living things. There are three main effects of the electromagnetic fields produced by power circuits. They are biological effects (living things), interaction with sensitive electronic devices, and the effect of electromagnetic fields on power circuit electric current distribution. Insulation failures and circuit overheating can result from uneven current distribution. Electromagnetic devices are affected by non-living entities. For example, the term "skin effect" refers to the magnetic property that, as an AC current's frequency increases, confines it to the outside of a conductor. Higher resistive losses directly proportionate to frequency will result from the effect's reduction in area as opposed to the conductor's real cross-sectional area. Therefore, the skin effect may result in additional losses or the requirement to oversize conductors for higher order harmonics. Research on the effects on gadgets has been conducted and is ongoing as technology advances. Their effects are regulated through standards. The heating of biological tissues caused by low-frequency, minuscule circulation currents created by external electric and magnetic fields is the principal effect of radio frequency electromagnetic radiation [5]. Because of the widespread use of digital technology, equipment in residential, commercial, and industrial settings is more vulnerable to electromagnetic interference (EMI) from both internal and external sources. Recent reports have indicated a rise in power quality issues caused by the connectivity of renewable energy systems [6].

In contemporary power distribution networks, harmonic disturbances are the main factor contributing to power quality degradation, and the main causes of these disturbances are nonlinear loads that contain power electronic switches [7] [2]. Nowadays, non-linear equipment is used more often at all electrical system levels — industrial and residential — because of its unique properties [8]. Conventional nonlinear household appliances, such as air conditioners and refrigerators, have electromagnetic components like transformers and motors [9] and within the power network, harmonics are primarily produced by nonlinear loads like computers, laser printers, converters, refrigerators, TVs, etc. [10]. These modern electronics loads produce harmonics as a result of the switched mode power sources they use [11] [12]. A selection of common appliances from the home to business sectors is displayed in Table 2. It is typical a common practice to use various converter levels to improve the power quality of large-power induction motor drives [13]. Furthermore, data centers have grown to be significant energy users, because of their enormous scale, their effect on power quality has grown to be a significant worry that requires careful design [14]. Additionally, there's a chance that associated electromagnetic interference issues and electromagnetic compatibility issues that aren't covered by the current standards [15]. Not only are these devices susceptible to disruptions in power quality, but they also have the ability to cause such disruptions. Table 3 displays the emissions at the home level from a few of these devices.

Research has demonstrated that the impacts of harmonics have caused a notable decline in equipment performance [16] [17]. Power quality must therefore, be improved and safety must be provided because nonlinear loads produce harmonics that distort system voltage [18] [19]. Nonlinear loads, heavy-duty switches, and strong electronics converters can cause power quality issues that cause variations in supply voltage, supply frequency, and/or waveform deviation [19].

Table 2: Common Modern Electromagnetic Appliances

Domestic	Commercial	Industrial
Televisions (TV)	Workstations, Micro wave Transmitter and Receivers	Programmable logic controllers (PLC)
Video cassette recorders (VCR)	Personal Computers (PCs), Laptops	Automation & data processors,
Microwave ovens,	Copiers	Variable speed drives (VSD)
Personal computers (PCs), Laptops, Palm-tops	Printers	Soft starters
Heating-ventilation-air conditioning equipment (HVAC)	Lighting	Inverters
Dishwashers		Computerized numerical control (CNC) tools
Dryers		

Table 3: Low-frequency *Electromagnetic force* due to common household Equipment

Equipment	EMF 6in. from Surface (mG)
Personal computer	25
Microwave	75
Range	150
Baseboard heater	40
Electric shaver	20
Hair dryer	150
Television	25

Figure 1 illustrates basic relation of harmonic current emission, interaction and coupling of disturbances.

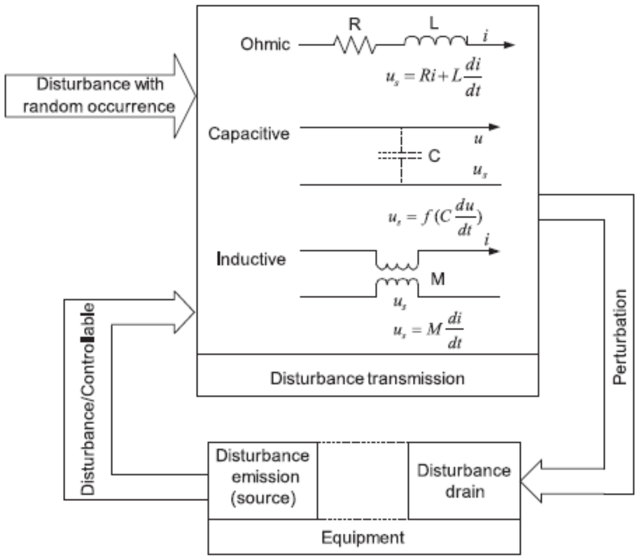

Figure 1: Basic relation of harmonic current emission, interaction and coupling of disturbances [20]

2. Basic concept of Electromagnetic Disturbances and Definitions of Some Electromagnetic Phenomena

Electromagnetic Compatibility (EMC), is the capacity of a system or piece of equipment to operate in its electromagnetic environment without causing anything in that environment to become unbearably disturbed and any electromagnetic event that can negatively impact living things or inert matter, or reduce the efficiency of a device, piece of machinery, or system, is referred to as an electromagnetic disturbance. A change in the propagation medium itself, an undesired signal, or electromagnetic noise could be the cause. Its presence in the electromagnetic environment can lead to electrical equipment not functioning as intended.

Disturbance level is defined as the amount or magnitude of an electromagnetic disturbance, measured and evaluated in a specified way. The disturbance is a function of i) emission ii) compatibility iii) susceptibility and iv) immunity of each device. While emission has to do with the origin of the disturbance; susceptibility deals vulnerability of the device. On the other hand, immunity deals with ruggedness of the device.

Conducted disturbance is electromagnetic phenomenon which propagates along the electricity supply conductors and/or signal-control connections. Disturbances in transmission distribution systems have the ability to spread along power lines and occasionally across transformers, affecting equipment that is far from the source. Harmonics, voltage dips and short supply interruptions, voltage imbalance, and main frequency variation are the primary categories of conducted disturbances. The conducted disturbances have the potential to impact adjacent equipment and can be conveyed via conduction or inductive couplings [21].

A summary of some of the definitions for various electromagnetic phenomena may be found in Table 3. Based on temporal statistics, they are typically designated as 95% probability values.

Table 3: Definitions of Some Electromagnetic Phenomena

s/n	EMC Phenomenon	Definition	Typical value
1	Electromagnetic Compatibility level	The specified disturbance level at which an electromagnetic compatibility should exist.	95 %
2	Disturbance level	The value of a given electromagnetic disturbance, measured in a specified way.	95 %
3	Total disturbance level	The level of a given electromagnetic disturbance caused by the superposition of the emissions of all pieces of equipment in a given system	95 %
4	Emission level	Level of a disturbance injected into the surrounding space or into the supply conductors	95 %
5	Immunity level	Immunity level the maximum level of a given electromagnetic disturbance, incident in a specified way on a particular device, equipment or system, at which no degradation of its specified performance occurs	95 %
6	Planning level	The specified disturbance level used mainly for planning purposes in evaluating the impact on the system of all disturbing consumers or equipment.	95 %

The effect of radiation on human health is still under constant investigation. Medical scientists are linking increase in pathological diseases such as cancers to increasing human exposure to radiation beyond acceptable level. Generally human immunity differs based on certain factors. The greatest level of an electromagnetic disturbance or incident that affects a specific device, piece of equipment, or system without causing any degradation in its intended performance is known as its immunity level. Table 3 shows immunity and power quality indices for some equipment.

Table 4: Immunity and Power Quality

Index	Description	Examples
Equipment Immunities Indices		
I	High immunity	Motors, transformers, incandescent lighting, heating loads, electromechanical relays
II	Moderate immunity	Electronic ballasts, solid-state relays, programmable logic controllers, adjustable speed drives
III	Low immunity	Signal, communication and data processing equipment; electronic medical equipment.
Power Quality Indices		
I	Low power quality problems	Service entrance switchboards, lighting power distribution panel,
II	Moderate power quality problems	HVAC power panel
III	High power quality problems	Power supplying adjustable drives, elevators, large motor

3. Electromagnetic Disturbance and Power Quality

Disturbance propagates from its source, which can be nonlinear loads, short circuits, equipment starts and stops, or the power system. On the utility side, switching operations, failures, and lightning are the main causes of power quality problems; however, nonlinear loads, poor grounding, electromagnetic interference, and static electricity pose a number of technical difficulties on the end-user side. Voltage fluctuations and flicker, harmonics up to and including order 50, inter-harmonics up to the 50th harmonic, voltage distortions at higher frequencies (above the 50th harmonic), voltage dips and brief supply interruptions lasting up to three minutes, voltage unbalance, transient over voltages, power frequency variation, d.c. components, and mains signaling are among the electromagnetic disturbance phenomena that are typically taken into consideration. The conventional classification of these disturbances is shown in Table 5.

Table 5: Classification of electromagnetic phenomena according to IEC.

Conducted low-frequency	**Harmonics and inter-harmonics**
	Signal systems (power line carrier)
	Voltage fluctuations
	Voltage sags and interruptions
	Voltage imbalance
	Power-frequency variations
	Induced low- frequency voltages
	DC in AC networks
Radiated low-frequency	Magnetic fields
	Electric fields
Conducted high-frequency	Induced continuous wave voltages or currents
	Unidirectional transients
	Oscillatory transients
Radiated high-frequency	Magnetic fields
	Electric fields
	Electromagnetic fields
	Continuous waves
	Transients

Power quality is a serious problem that practically all consumers in the commercial, industrial, and residential sectors face [22]. It should be mentioned that different problems and impacts on electrical power system devices with regard to the propagation characteristics of low-frequency and high-frequency distortions may develop because power electronics converters are present in installations or distribution systems [23]. Even if it's not feasible to totally eradicate PQ disruptions, this ought to be maintained at acceptable levels [24]. One of the main priorities for all designers and producers of electric equipment should be ensuring that the requirements are being followed throughout the complete frequency range in engineering practice [15]. Typically, verification from the perspectives of PQ and EMC must be completed concurrently [15]. As a result, electromagnetic interference must be managed, primarily by reducing emissions brought on by all kinds of electrical and electronic devices. The Electromagnetic Compatibility Directive in the European Union addresses this issue, whereas the IEEE Standards serve as the primary source of guidance in the United States. While Nigerian GSM carriers asserted compliance with pertinent international standards, there is a chance that non-compliance at the base station could result from inadequate monitoring [25].

3.1 EMC Standards

The European Committee for Electrotechnical Standardization (CENELEC), the CISPR, and the IEC organizations are the primary sources of standards incorporated into the EMC Directive. The criteria aid in both obtaining and managing sufficient electricity quality. They offer a framework for defining the surroundings of electrical distribution networks, the equipment's sensitivity to poor voltage quality, and the emissions from various kinds of equipment.

The primary goal of the EMC standard is to guarantee that:

i) The amount of disturbance from each individual source is such that the total amount of disturbance from all sources does not surpass the standard level of disturbance that is expected in the environment.

ii) To allow for the proper, stipulated level of performance at the typically expected degree of disturbance, equipment immunity is supplied.

4. Mitigating the Impact of Electromagnetic Phenomena

Mitigating the impact of electromagnetic phenomena can involve various strategies and techniques to minimize potential negative effects on human health, electronic equipment, and sensitive systems. The following can be adopted for mitigating the impacts.

1. Compliance with regulatory standards. Government to ensure standard body and regulatory

body are effectively in place. Adhering to electromagnetic compatibility standards and regulations ensures that devices meet specific requirements regarding emissions, susceptibility, and safety. Compliance with these standards ensures that electromagnetic impacts are within acceptable limits and reduces the risk of interference. While it cannot be totally true that the populace is ignorant of side effects of technology; their ignorance speaks volume of this. The regulatory agencies can because of pecuniary gain compromise the standard.

2. Installation Techniques: Employing adequate techniques such as maintaining adequate distance between electromagnetic devices and sensitive equipment or individuals can help reduce the impact of electromagnetic radiation. Positioning sensitive devices away from strong electromagnetic sources and minimizing exposure time can help mitigate potential risks.

3. Design concept and philosophy: Electromagnetic disturbances cause power quality issues, which start at the source and spread throughout the power system, sometimes even to other pieces of equipment. Power distribution circuit design must consider these occurrences in order to prevent these issues. Derated conductor ampacities can be used to specify circuit conductor sizes in order to account for the consequences of uneven current distribution. Electromagnetic Compatibility (EMC) Design concept and philosophy ensure that electronic devices are designed and constructed to minimize electromagnetic emissions and susceptibility. This involves proper shielding, grounding, and layout techniques to reduce electromagnetic interference (EMI) and enhance device immunity.

4. Effective protection methods: This entails appropriate shielding, which entails building barriers that prevent or reroute electromagnetic fields using materials like conductive metals or alloys. By doing this, electromagnetic radiation cannot enter sensitive locations. Devices, cables, enclosures, and rooms can all benefit from shielding in order to lower electromagnetic emissions or shield delicate equipment from outside electromagnetic interference.

5. Proper Earthing and Bonding: Proper earthing and bonding techniques are essential for reducing electrical noise and ensuring the stability of electrical systems. Grounding involves connecting devices and systems to a common ground reference, while bonding involves creating low-resistance paths between different metallic components. Both techniques help to minimize the effects of electromagnetic interference.

6. Filtering: Electromagnetic interference filters or EMI filters are components that suppress unwanted electromagnetic emissions or attenuate external interference. These filters are often integrated into electronic devices, power supplies, or data communication lines to reduce electromagnetic noise.

7. Configuration: Circuit configuration layout can minimize electromagnetic coupling between different components and reduce the risk of interference. Techniques such as separating high-current and high-frequency traces from sensitive analog or digital circuits, using proper grounding techniques, and minimizing loop areas can help mitigate electromagnetic impacts.

8. Enlightenment campaign to educate the masses on the danger of radiation. Promoting education and awareness about electromagnetic radiation, its potential effects, and mitigation techniques is essential. This includes training for device manufacturers, engineers, and users to understand the risks associated with electromagnetic devices and how to mitigate them effectively.

5. Conclusion

The importance of electromagnetic phenomena cannot be overemphasized in modern times, especially with advancing technology. From communication to transportation, electromagnetic waves play a crucial role in various aspects of daily lives. Understanding and harnessing these phenomena have led to groundbreaking innovations that continue to shape the world. This study has examined the impact of electromagnetic phenomena and power quality disturbances generally, highlighting the importance of understanding and managing these factors to maintain a safe and efficient electrical environment. It is crucial for stakeholders to collaborate in developing strategies and technologies that prioritize both functionality and environmental responsibility. The basic concepts involved in electromagnetic disturbance and power quality were highlighted along with relevant definitions. Overall, various strategies to mitigate these impacts were also presented. Additionally, the importance of ongoing monitoring and maintenance to address potential issues before they escalate was emphasized. By implementing these strategies, businesses can not only improve their operational efficiency but also reduce their environmental footprint.

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