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ANALYZING THE IMPACT OF POWER QUALITY ON NAVAL PLATFORM ELECTRICAL SYSTEMS

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ABSTRACT:

The purpose of this study is to examine the impact of power quality on the electrical systems used by naval platforms in great detail. The electrical infrastructure aboard naval boats is very susceptible to transient disturbances, harmonic distortion, frequency deviations, voltage stability, and performance issues. Using a literature review, case studies, and technical assessments as a framework, this research investigates how power quality changes impact electrical energy transmission, distribution, and use in naval contexts. In addition, it delves into methods for reducing risks, technical fixes, and recommended practices for improving electrical system performance and power quality in harsh marine environments. Naval engineers, lawmakers, and stakeholders engaged in the design, operation, and maintenance of naval platform electrical systems may benefit greatly from the insights provided by this study, which synthesizes current information and identifies research needs..

Keywords: Power quality, Naval platforms, Electrical systems, Voltage stability, Frequency deviations, Harmonic distortion.

I. INTRODUCTION

When it comes to naval platforms, engineering has reached its zenith; these vessels combine state-of-the-art technology with strategic capability and operational agility to accomplish a wide range of maritime operations. Sophisticated electrical systems power the propulsion, navigation, communication, armament systems, and onboard operations of these fearsome boats. The mission's success, operational preparedness, and the welfare of people deployed at sea are directly correlated to the dependability, efficiency, and security of these electrical systems. However, electrical infrastructure aboard naval ships is particularly vulnerable to threats to its integrity and stability in the marine environment, including voltage variations, frequency deviations, harmonic distortions, and transient disturbances. [1].

Even little variations from optimal operating conditions may have significant effects on operational efficacy and crew safety, highlighting the indisputable importance of power quality on electrical systems of naval platforms. For example, compromised situational awareness and mission-critical activities might result from equipment failure, system unavailability, and operational interruptions caused by voltage instability. On the other hand, fluctuations in frequency may disrupt electrical equipment's synchronization, which in turn can cause power distribution inefficiencies and even damage to delicate electronic parts. Electrical systems have extra difficulties due to harmonic distortion, which causes insulation to fail, electromagnetic interference, and overheating. Additionally, equipment may be damaged and system dependability compromised due to transient disturbances that create voltage spikes, surges, and transients.

It is critical to thoroughly examine how power quality affects the electrical systems on board naval platforms because of their strategic relevance and the ever-changing nature of maritime operations. In order to better understand how ships, submarines, and other maritime assets handle electrical energy, this study will investigate the many facets of power quality in naval contexts. The study's goal is to educate stakeholders, including naval engineers, lawmakers, and others about the significance of power quality management in guaranteeing operational readiness and mission success by outlining the difficulties, risks, and possible remedies linked to power quality fluctuations.

Voltage stability, frequency deviations, harmonic distortion, and transient disturbances are some of the power quality characteristics that are commonly seen in naval environments. This analysis will cover all of these topics, including where they come from, what they do, and what they mean for the electrical systems on naval platforms. This project will analyze real-world occurrences involving power quality and how they affected equipment performance, system dependability, and mission effectiveness. It will do this via reviewing literature, conducting case studies, and doing technical analysis [2].

In addition, the research will look at ways to improve power quality and optimize electrical system performance in marine settings, as well as technical solutions, best practices, and mitigation methods. The effectiveness, feasibility, and cost implications of various techniques, equipment upgrades, filtering devices, voltage regulators, frequency converters, and advanced monitoring and control systems in addressing power quality issues on naval platforms will be assessed.

The overarching goal of this research project is to provide naval engineers, operators, and lawmakers with useful information for electrical system design, operation, and maintenance. Ensuring the reliability, safety, and effectiveness of electrical systems aboard naval platforms in an increasingly complex and challenging maritime environment is the goal of this study, which aims to contribute to the advancement of power quality management practices in maritime applications by addressing the complex interplay between power quality, operational requirements, and mission objectives [3].

II. LITERATURE REVIEW

Lipan, Laurentiu & Stoican, N.. (2010) A research on power quality in an offshore drilling environment was conducted and the findings are presented in this publication. A complicated system with considerable voltage changes (flicker effect), a distorting regime, and an important variable reactive power are all components of the examined platform, which includes several electric receivers with diverse characteristics that define the power bar 600 V. Collecting data samples at many NPS (Naval electricity Systems) characteristic sites on the electricity system was essential for proposing a workable technoeconomic solution. The measurement data is typical, however it did not deviate from the generators' maximum request intervals (the primary drive engine was not operating at full load throughout the test). [4].

Barros, Julio & Diego, Ramón. (2016) There is growing concern about the quality of electric power in ship power system networks. Not only does low-quality electricity impact the functionality of the ship's electrical systems, but it also significantly impacts energy efficiency, navigational safety, and marine life safety. This study provides a comprehensive literature analysis of the most important developments concerning ship power quality. Topics covered include harmonic distortion, voltage imbalance, transients, transient voltage peaks and valleys, transient voltage dips and swells, fault detection and classification, and more. Lastly, shipboard electrical systems' power quality instrumentation and requirements are also taken into account. [5].

Mindykowski, Janusz & Tarasiuk, Tomasz. (2015) The impact of poor electrical power quality on maritime safety is the topic of this article. New techniques for producing and using electrical energy in ship systems have raised the apparent relevance of power quality in recent years. Thus, ship classification organizations, crew members, and ship designers face new obstacles. In this work, we take a look at these difficulties from a legal and ethical engineering perspective. The document explains the authors' position on the continuing debate that followed the Queen Mary 2 disaster. Questions that are briefly addressed by the writers include: What metrics may be used to characterize the power quality of ship systems? Which constraints are to be enforced? When, where, and how can we tell whether the electricity is good? Lastly, how can power quality regulations and practices be enhanced by ship classification organizations to forestall the disastrous outcomes that would result from a decline in power quality? [6].

Tarasiuk, Tomasz et al., (2021) Ship microgrids are the topic of this paper's discussion of current issues. Power quality challenges, including traditional ones like voltage and frequency fluctuations, as well as newer ones such waveform distortions caused by the widespread usage of power electronics in ship microgrids, are the main points of this article. Discussion of Total Harmonic Distortion (THD) definition and other aspects of the Unified Requirements of International Association of Classification Societies and other industry-leading power quality standards is also included in the paper. Additionally, the effects of power converters on ship networks and their use in high-power maritime applications are outlined. The next section presents and discusses the original findings of several power quality phenomena reported in ship microgrids. It then moves on to a review of the literature and offers suggestions for marine microgrid modeling and signal processing approaches that may be used to evaluate power quality in the systems that have been described. Lastly, we provide some first suggestions for power quality management. [7].

Zhuk, Dmytro et al., (2021) Energy efficiency of technical fleet specialist boats is related to the work's significance. This study set out to analyze the marine platform support vessel's electrical power system, which includes strong semiconductor propulsion electric drives, and identify and assess power quality indicators related to the non-sinusoidal voltage and current curves. The study also took into consideration the parasitic and inherent parameters of the power three-phase cable lines. The study's goal was to analyze analog systems characteristic of the stated kind of vessels and construct a reduced one-line schematic of an electric power system with a DC main bus. The study's focus was on the impact of higher harmonics produced by power semiconductor converters on voltage and current distortion in a three-phase ship network. The electric power system's simplified one-line scheme was used to develop the model in MATLAB Simulink, which was then used for experimental studies of power quality. A system for the trustworthy estimation of model parameters was established based on the known ways of calculating the ship's electrical equipment. The experimental results in MATLAB Simulink provided both qualitative and quantitative indicators of the non-sinusoidality of the three-phase network's linear voltage and current. These indicators included curve shapes, amplitude spectra, and distortion coefficients, which were then compared to the current norms and standards. Unlike earlier approaches, this one considers the studied electric power system's circuit, mode characteristics, and the presence of a parasitic capacitance "phase to ground" of a three-phase network when evaluating electricity quality; it can be applied to solve comparable non-trivial problems for other structurally modified systems. [8].

III. POWER QUALITY CHARACTERISTICS IN NAVAL ENVIRONMENTS

1. **Voltage Stability:** Voltage fluctuations are common in naval settings caused by changes in load demand, interruptions in grid functioning, and generator activity. If the electrical systems and equipment aboard naval platforms are to continue functioning reliably, voltage stability must be maintained.

2. **Frequency Deviations:** Radar, communication, and navigational devices are power-sensitive and may be negatively affected by frequency variances that occur as a result of changes in generator speed or grid synchronization. [9].

3. **Harmonic Distortion:** Harmonic distortion, which may occur aboard naval platforms due to nonlinear loads and switching processes, can lower the electrical power quality. System performance and dependability may be negatively impacted by harmonics, which can lead to insulation failure, overheating, and interference with sensitive electronic equipment.

4. **Transient Disturbances:** The existence of switching loads and the ever-changing nature of onboard activities make transient disturbances like voltage spikes, surges, and transients prevalent in naval situations. Damage to equipment, interruptions to system performance, and dangers to worker safety may result from these disruptions. [10].

5. **Electromagnetic Interference (EMI):** Onboard electronics, propulsion systems, and even outside electromagnetic fields may all cause electromagnetic interference on naval ships. Electromagnetic interference (EMI) poses a threat to mission efficacy and operational safety by interfering with navigation, communication, and sensor systems.

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6. Voltage Sags and Swells: Marine platforms' electrical systems are vulnerable to voltage dips and spikes brought on either unanticipated shifts in load demand or disruptions to the power grid. Equipment failure, system instability, and interruptions in operations may result from these voltage changes. [11].

7. Voltage Unbalance: Unexpected changes in load demand or power grid outages may cause voltage dips and spikes, which can damage the electrical systems of marine platforms. Voltage fluctuations provide a threat of equipment breakdown, system instability, and operational disruptions.

8. Power Quality Monitoring: In order to detect, analyze, and alleviate power quality problems aboard naval systems, it is crucial to monitor power quality attributes effectively. Various factors, including voltage, frequency, and harmonics, may be monitored in real-time by power quality monitoring systems. This helps to guarantee that electrical systems are reliable and safe. [12].

9. Mitigation Strategies: Onboard naval systems, power quality difficulties may be mitigated using a variety of measures, including isolation transformers, transient suppressors, voltage regulators, and harmonic filters. Reliable functioning of electrical systems in demanding marine conditions is ensured by these solutions, which attempt to reduce voltage fluctuations, harmonic distortion, and transient disturbances.

10. Training and Education: In order to educate the public and encourage the adoption of best practices for managing power quality aboard naval systems, training programs and educational activities are vital. In order to make marine electrical systems more resilient and reliable, crew members, engineers, and maintenance staff should undergo training on power quality principles, mitigation strategies, and safe operating practices. [13].

IV. MITIGATION STRATEGIES AND TECHNOLOGICAL SOLUTIONS

To guarantee the dependability, efficiency, and security of electrical systems aboard naval platforms, it is crucial to handle power quality issues in naval settings using a mix of mitigation tactics and technology solutions. [14].

1. **Active Power Filters:** By using sophisticated management algorithms and semiconductor devices, active power filters effectively reduce harmonic distortion in electrical systems. Effectively reducing harmonic distortion levels and improving power quality aboard naval vessels, active power filters inject compensating currents that cancel out harmonic currents. [15].

2. **Voltage Regulators:** Static voltage regulators (SVRs) and dynamic voltage restorers (DVRs) are two types of voltage regulators used on naval platforms to stabilize voltage levels and reduce voltage fluctuations. In order to control the output voltage, SVRs move the tap locations on the transformer, while DVRs use energy storage and power electronics to correct the voltage in real time.

3. **Transient Suppressors:** To safeguard electrical equipment against transients, surges, and spikes in voltage, transient voltage suppressor (TVS) diodes, surge protectors, and voltage clamps are often used. These devices protect delicate equipment against short-lived surges by redirecting the energy away from it. [16].

4. **Isolation Transformers:** Naval platforms' electrical systems are able to withstand common-mode and differential-mode noise thanks to isolation transformers, which isolate the main and secondary windings electrically. Isolation transformers improve power quality and eliminate electromagnetic interference by separating sensitive equipment from ground loops and outside disturbances.

5. **Active Harmonic Filters:** To dynamically eliminate harmonic currents produced by nonlinear loads aboard naval systems, active harmonic filters use control algorithms and power electronics. Active harmonic filters may lower harmonic distortion levels and guarantee compliance with power quality requirements by continuously monitoring and adjusting for harmonic currents. [17].

6. **Power Factor Correction:** To enhance power factor and minimize reactive power consumption in electrical systems aboard naval ships, power factor correction (PFC) methods like capacitive or inductive power factor correction are used. Installing reactive power offset capacitors or reactors from a PFC system optimizes efficiency, which in turn improves power quality and reduces losses..

7. **Advanced Monitoring and Control Systems:** Shipboard naval platforms can now monitor power quality metrics including voltage, frequency, harmonics, and transient disturbances in real-time thanks to advanced monitoring and control systems. In order to avoid power quality concerns from becoming worse, these systems provide important information about the state and performance of electrical systems, which allows for proactive diagnosis and maintenance. [18].

8. **Energy Storage Systems:** Naval vessels may be outfitted with energy storage equipment, such batteries or supercapacitors, to provide backup power and voltage stability. Energy storage devices improve the dependability and resilience of systems in ever-changing marine settings by storing surplus energy during off-peak hours and delivering extra power during short-lived events or disruptions to the grid.

9. **Fault Detection and Diagnosis:** Naval platforms equipped with fault detection and diagnostic systems are able to identify and assess power quality problems, equipment breakdowns, and anomalous operating circumstances via the use of sophisticated algorithms and sensors. These technologies may decrease downtime and guarantee operational availability by spotting possible problems or abnormalities early and enabling rapid intervention and preventative maintenance [19].Naval platforms equipped with fault detection and diagnostic systems are able to identify and assess power quality problems, equipment breakdowns, and anomalous operating circumstances via the use of sophisticated algorithms and sensors. These technologies may decrease downtime and guarantee operational availability by spotting

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possible problems or abnormalities early and enabling rapid intervention and preventative maintenance [19].

10. **Integrated Power Management Systems:** To maximize the efficiency, dependability, and performance of energy, naval vessels use integrated power management systems (IPMS) to coordinate the operation of various power sources, loads, and energy storage devices. Improved power quality, reduced fuel usage, and overall system resilience in demanding marine conditions are all outcomes of intelligent power flow, distribution, and utilization management systems (IPMS). [20].

V. THE ELECTRICAL DIAGRAM OF NPS (NAVAL POWER SYSTEMS)

The platform that was examined includes a power plant that uses six synchronous electric generators. Each generator has a nominal output of 1400 kVA, a nominal power factor of 0.8, a notional current of 1408 A, and a nominal voltage of 600 V at the terminals. There are two voltage levels in the electric scheme (Fig. 1): 600 V for the platform's primary motors and 400 V for other receivers (e.g., operational systems, electric lights). [21]

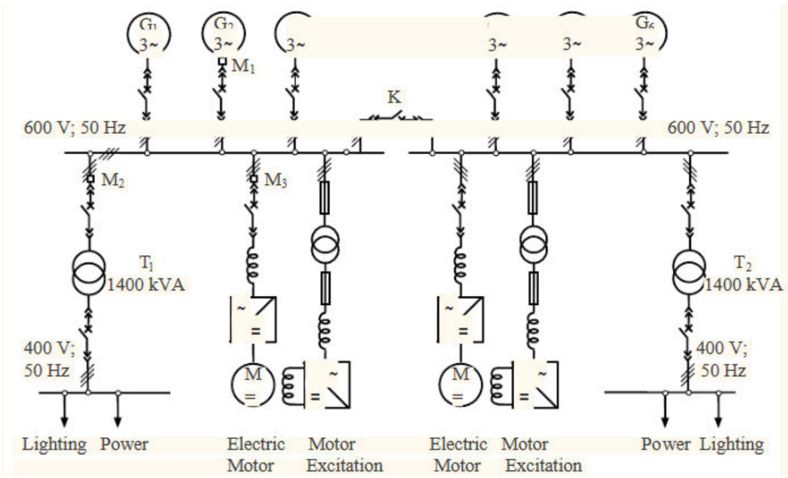

Figure 1. The scheme of the electrical circuit of the platform

The platform's primary propulsion systems are d.c. volts, which are supplied by converters, and are excited in parallel. By modifying the amount of electric current in the electric machine's main circuit, the speed can be adjusted according to the machine's load. [22]

VI. ANALYSIS OF THE DISTORTION PHENOMENA IN THE ELECTRICAL CIRCUIT OF THE PLATFORM

The measurements were performed with performance monitoring and measurement equipment following, in particular, the level of distortion in different parts of the scheme. Platform-specific technological process leads to a strong variability of both active power consumption and reactive power, which leads, naturally, a variable power factor, and lack of reactive power compensation systems. Power factor values recorded in different operating conditions can be seen in Fig. 2. We can observe variation of power factor between 0.45 and 0.82.

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Figure 2. Values recorded by the local equipment (U, I, P, λ)

Considered here is the power factor λ, which is defined as the ratio of active power (P) to perceived power (S).

$$\lambda = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2 + D^2}}$$

……………………………(1)

The presence of receivers that cause non-active power and severe nonlinear distortion curves;

- the critical importance of reactive power in the platform's electrical diagram;
- and the distortion power, D, which is a function of Q. [23]

VII. CONCLUSION

Making sure the electrical systems on naval platforms are reliable, perform well, and safe is of the utmost significance, as shown by the examination of power quality features and mitigation techniques in naval settings. Managing power quality concerns efficiently requires a comprehensive strategy due to the dynamic nature of maritime operations and the inherent constraints of the marine environment. Policymakers, operators, and naval engineers can better understand power quality characteristics like transient disturbances, harmonic distortion, frequency deviations, and voltage stability in order to develop and implement technological solutions that mitigate these challenges. The use of active harmonic filters, isolation transformers, transient suppressors, voltage regulators, active power filters, and other cutting-edge technology allows naval platforms to improve power quality, minimize disturbances, and maximize system performance.

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