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INFLUENCE OF HIGHER HARMONICS ON POWER QUALITY IN INDUSTRIAL ELECTRICAL NETWORKS

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Abstract. *This article examines the influence of higher harmonics on the power quality in industrial electrical networks. It highlights the causes of harmonic distortion, the types of nonlinear loads that generate harmonics, and the wide range of negative effects on energy efficiency, equipment performance, and industrial processes. Key issues such as energy losses, equipment overheating, malfunctioning of protective devices, and inaccuracies in metering systems are analyzed. The study emphasizes the importance of monitoring Total Harmonic Distortion (THD) levels according to international standards like IEEE 519-2014 and IEC 61000-4-7. Effective mitigation strategies, including the use of active and passive harmonic filters, proper network design, and continuous power quality monitoring, are discussed. A systematic and dynamic approach to managing harmonic distortion is identified as essential for maintaining energy efficiency, equipment reliability, and the stability of industrial production.*

Keywords: *Higher harmonics, power quality, industrial electrical networks, harmonic distortion, Total Harmonic Distortion (THD), active filters, passive filters, energy efficiency, equipment reliability, power monitoring, IEEE 519-2014, IEC 61000-4-7.*

Introduction. In the context of modern industry, power quality has become a critical factor that determines the reliability of equipment operation, the efficiency of production processes, and the economic viability of energy systems' operation. One of the most significant factors influencing power quality is the presence of higher harmonics in industrial electrical networks. Harmonics arise as a result of nonlinear processes occurring during the interaction of electrical current and voltage with various system elements, posing a serious threat to the stability and longevity of electrical equipment.

Research results. Higher harmonics are components of an electrical signal whose frequencies are integer multiples of the fundamental network frequency, typically 50 or 60 Hz. Nonlinear loads such as variable frequency drives (VFDs), switched-mode power supplies, electric furnaces, welding equipment, and lighting systems based on LED technologies actively generate harmonic distortions. The presence of higher harmonics alters the ideal sinusoidal waveform of voltage and current, leading to various undesirable physical and economic consequences.

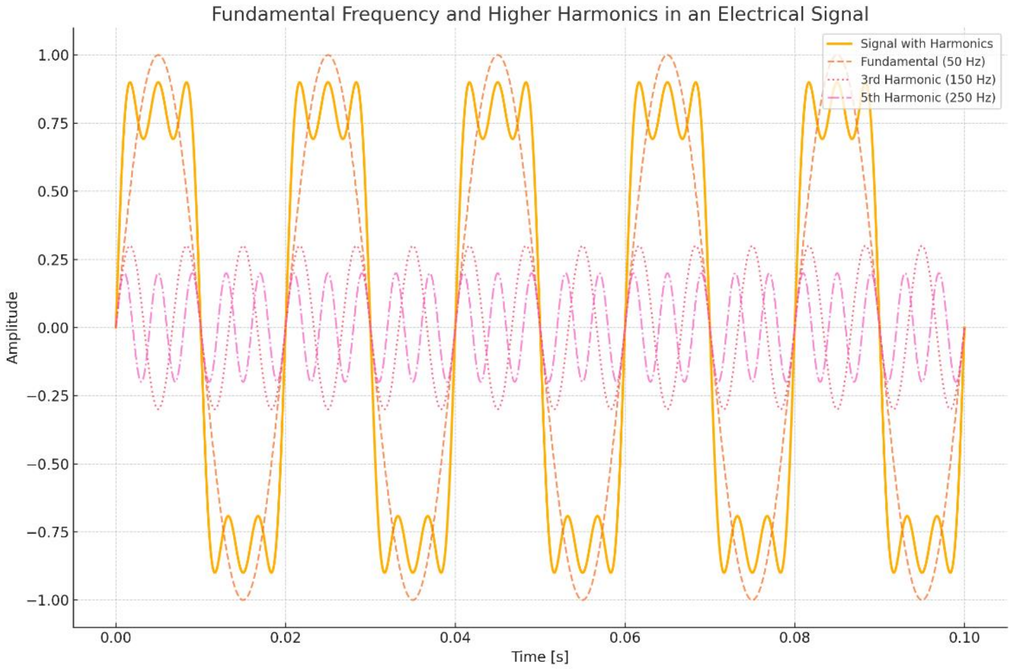

Figure 1 - Fundamental Waveform and Higher Harmonic Components in an Electrical Signal

One of the main negative effects of higher harmonics is the increase in energy losses within elements of the power supply system. Harmonic currents cause additional heating of cable lines, transformers, and electric motors due to the increased effective resistance of conductors at higher frequencies. Consequently, energy consumption increases without delivering useful work, leading to a decrease in the overall energy efficiency of industrial enterprises. In heavily loaded networks, these additional losses can reach substantial levels, necessitating increased cooling capacity and resulting in accelerated equipment aging.

Another serious consequence is the adverse impact of harmonics on the operation of protective devices. Many protection devices, such as circuit breakers and relay systems, are designed to operate with pure sinusoidal currents. The presence of harmonics can lead to the malfunctioning of these devices, reducing their sensitivity or, conversely, causing false tripping, which increases the risk of accidents and unplanned downtime in industrial electrical networks.

Higher harmonics also have a direct negative impact on the operation of electric motors, causing overheating of windings, reduction of torque, increased mechanical vibrations, and, over time, accelerated wear of motor components. In continuous production processes, where equipment reliability is paramount, the degradation caused by harmonics can result in significant production losses and increased maintenance costs. Motors subjected to continuous harmonic stress tend to have shorter lifespans and require more frequent repairs or replacements, affecting overall productivity and profitability.

The influence of harmonics extends to the accuracy of metering and control devices. Instruments used for energy monitoring and control may provide incorrect readings when operating in distorted conditions, leading to inaccurate energy audits and making it difficult to implement effective energy management strategies. This misrepresentation of power parameters can hinder efforts to optimize energy use, detect inefficiencies, and achieve operational excellence.

To assess the level of harmonic distortion, the Total Harmonic Distortion (THD) index is used, which measures the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. International standards such as IEEE 519-2014 and IEC 61000-4-7 establish permissible THD levels for different classes of networks and loads, setting benchmarks for the acceptable quality of supplied electricity and encouraging enterprises to monitor and control these parameters systematically.

In response to the threat posed by harmonic distortions in industrial electrical networks, a range of technical solutions has been developed and implemented. One of the most effective methods is the installation of active and passive harmonic filters. Passive filters are typically tuned to specific harmonic frequencies and provide effective attenuation at those points. Active harmonic filters, on the other hand, dynamically analyze the harmonic content and inject compensating currents in real-time, offering superior flexibility and effectiveness, especially in dynamic industrial environments with frequently changing loads.

Additional measures include the proper design and layout of electrical networks, taking into account the need to minimize the impact of nonlinear loads. This includes distributing loads evenly across phases, grouping harmonic-generating loads separately, and applying network segmentation strategies. Using isolation transformers for critical equipment and applying phase-shifting transformers are also recognized practices for mitigating harmonic propagation.

Constant monitoring of power quality parameters is another vital component in combating harmonic issues. Advanced power quality analyzers can record voltage and current waveforms in high resolution, enabling the identification of harmonic issues, flicker, voltage sags, and other disturbances before they escalate into serious problems. Historical data collected through monitoring allows for trend analysis, predictive maintenance, and the timely implementation of corrective actions.

It is important to emphasize that addressing harmonic distortion is not a one-time project but a continuous process. As production technologies evolve and new equipment is integrated into industrial systems, the harmonic profile of electrical networks changes, requiring ongoing adaptation of mitigation measures. Implementing a holistic strategy that combines real-time monitoring, advanced filtering technologies, network optimization, and periodic reassessment is key to ensuring long-term electrical system stability.

Thus, the influence of higher harmonics on the power quality in industrial electrical networks represents a complex, multifaceted challenge that demands systematic detection, thorough analysis, and effective mitigation. The use of modern diagnostic tools, advanced filtering technologies, and strategic network management practices allows enterprises to significantly enhance energy efficiency, prolong the lifespan of critical equipment, and ensure the uninterrupted operation of production processes in the highly competitive environment of modern industry.

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ВПЛИВ ВИЩИХ ГАРМОНІК НА ЯКІСТЬ ЕЛЕКТРОЕНЕРГІЇ В ПРОМИСЛОВИХ ЕЛЕКТРИЧНИХ МЕРЕЖАХ

Верьовкін Олександр

Анотація. *У статті розглядається вплив вищих гармонік на якість електроенергії в промислових електричних мережах. Проаналізовано причини виникнення гармонічних спотворень, типи нелінійних навантажень, які генерують гармоніки, а також широкий спектр негативних наслідків для енергоефективності, роботи обладнання та виробничих процесів. Розглянуто основні проблеми, такі як втрати енергії, перегрів обладнання, некоректна робота захисних пристроїв і неточності в роботі вимірювальних систем. У дослідженні підкреслюється важливість моніторингу рівня повного гармонічного спотворення (THD) відповідно до міжнародних стандартів, таких як IEEE 519-2014 та IEC 61000-4-7. Обговорюються ефективні стратегії зменшення впливу гармонік, зокрема використання активних та пасивних фільтрів, правильне проєктування мережі та постійний моніторинг якості електроенергії. Визначено, що системний та динамічний підхід до управління гармонічними спотвореннями є необхідним для підтримання енергоефективності, надійності обладнання та стабільності промислового виробництва.*

Ключові слова: *Вищі гармоніки, якість електроенергії, промислові електричні мережі, гармонічні спотворення, повне гармонічне спотворення (THD), активні фільтри, пасивні фільтри, енергоефективність, надійність обладнання, моніторинг електроенергії, IEEE 519-2014, IEC 61000-4-7.*