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Analysis of the Quality of Electrical Power in Distribution Networks and Its Impact on Load Performance in Al-Musayyib District

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Abstract: *For the sustainability of the electrical system and meeting up to date technical standards, it is crucial to analyze the power quality of local distribution networks. The present research is concerned with a detailed diagnostic study of the network condition in the Al-Musayyib district by using an integrated approach in which, both field observation and precise mathematical modeling are used. The study is to show that there is a direct correlation between voltage disturbances (transient voltage drop, harmonic distortion) and the loss in performance of sensitive electrical loads. This work expands on the conventional characterization of electrical issues and provides a qualitative insight into the mechanisms associated with the impact of electronic transformers and non-linear loads found in the residential and commercial market. This is done by simulation software: models representing the actual operational reality of the network were developed (Using MATLAB/Simulink) and results were extrapolated and system response predicted for various load conditions. The research is to detect not only the fault, but to find out best engineering solutions for voltage stability and invisible technical losses minimization as well. The relevance of this research paper comes from the fact that the research data was gathered from real data of a local work environment and the findings are representative for decision makers in terms of maintenance priorities and infrastructure development. The research involves the findings that can be correlated with the international level, such as IEEE 519, which is considered to be a sound scientific base to increase the level of electrical reliability and reduce the damage of electrical current fluctuations to electrical equipment and appliances, which in turn can increase energy efficiency and protect local investments of electrical appliances and equipment.*

Keywords: Al-Musayyib District, Distribution Networks, Electrical Power, Voltage Disturbances

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Introduction

Effective electrical power (Power quality) is the main condition for the sustainability and efficiency of modern electrical systems in general and particularly, given the rapid growth of the urban and industrial development in the Musayyib district in the Babylon Governorate. Due to the growing use of non-linear loads and electronic transformers, disturbances in voltage (Voltage Sags, Sudden Voltage Rise and Distortion) are prevalent and result in reduced life of electrical equipment and heat loss.

The significance of this study is the evaluation of the condition of the electricity grid in Al-Musayyib district at the moment, which has been affected by fluctuations caused by the aging of the feeders and the lack of consistency in connecting the electricity grid with alternative energy sources. The purpose of this work is to precisely analyze electrical power quality in the field with the help of advanced measuring equipment and then simulate the behaviour of real electrical loads in response to the fluctuations. These issues need to be resolved by gaining a thorough understanding of the time-series of energy use in the district which this research aimed to achieve by integrating field data with predictive mathematical models.

The value of this study is that it offers a practical solutions perspective for the decision makers in the Ministry of Electricity on how to reduce technical losses and to make the power supply more reliable, the study findings are not only theoretical but applicable engineering solutions too such as increase the power factors using the active harmonic filters which helps in increasing the efficiency of the electrical system and protects the investments in the consumer electrical equipment. This study opens new avenues in understanding dialectical relationship between the quality of electrical supply and load performance in hot climatic environment to which it is subjected which also impacts load performance, thereby augmenting the scientific rigour of the study in local and international context.

Materials and Methods

The type of research used in this work is descriptive-analytical method with an experimental method in order to get the result of the research, which is accurate and complete. The procedure used in this study is

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sequential method, which is methods that is used to gather data first in the field with the aid of measuring instruments. The next step in the methodology is the modelling phase where the electrical network is constructed using realistic network parameters and load conditions simulated over a 6-month period to cover various load conditions. (MATLAB/Simulink) This is followed by an analysis phase that is dedicated to the comparison of the power quality with actual load. International standards and possible technical deviations from the standard values are set. The comparison phase is based on comparison between the results of the experiments carried out in real application and the results of the simulation models for the purpose of calculating error ratios, calibrating mathematical models and identifying exact technical gaps. This integrated methodology allows having a complete engineering approach to electrical phenomena, which gives high reliability to the scientific research conclusions, and makes the results a referential applicable for the development of the local electrical networks and local climatic regions.

Case Study

The study is conducted in the Al-Musayyib district in Babylon Governorate, which is located in a strategic position between longitudes 44.25° and 44.45° East and latitudes 32.70° and 32.90° North, which makes it have a clear strategic importance. The district extends along the banks of the Euphrates River, geographically it is a distinguished position and it is a veritable laboratory for measuring the thermal variations and their interaction with the electrical loads, making it an ideal research model for this purpose. These spatial characteristics play a role in the development of energy consumption patterns and challenges, and thus contribute to the understanding of thermal and electrical dynamics in the selected residential sector. Figure 1 illustrates this.

Figure 1: Geographical location of Al-Musayyib district
(Source: Al-JumhuriyaŝIraqi Ministry of Planning, Urban Planning Directorate, Administrative Map of Al-Musayyib District and surrounding areas)

Figure 1 is crucial as it identifies the exact geographical boundaries of Al-Musayyib District, the primary focus area of this study. The map allows for a spatial understanding of the existing electrical power distribution network, showing how loads are distributed relative to transformer stations and feeder lines, which is essential for diagnosing power quality issues and proposing practical solutions.

Results

In the following tables, the analysis of the electrical data extracted from AFor distribution of the field measurements is presented.

Measured Voltage (V)	Nominal Voltage (V)
195v	220v
205V	220v

Table 1: Voltage Drop Measurements

Table 1 shows the measured voltage levels compared to the nominal 220 V. The recorded values (195 V and 205 V) indicate a significant voltage drop exceeding standard limits, affecting overall system performance

Improvement	After improvement	Before improvement	Variable
14%	92%	78%	load efficiency

Table 2: The effect of fluctuations on performance

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Table 2 highlights the impact of power quality enhancements on overall system performance. The measurements show an increase in load efficiency from 78% to 92%, representing a 14% improvement following the technical interventions.

Technical status	THD%	Current	Load Sector
acceptable	8.2	15	Residential
critical	14.5	45	commercial

Table 3: Compatibility indicators in load currents

Table 3 compares harmonic distortion (THD%) and current levels between residential and commercial loads. Commercial loads exhibit critical THD levels reaching 14.5% at 45 A, requiring targeted harmonics mitigation compared to acceptable residential levels.

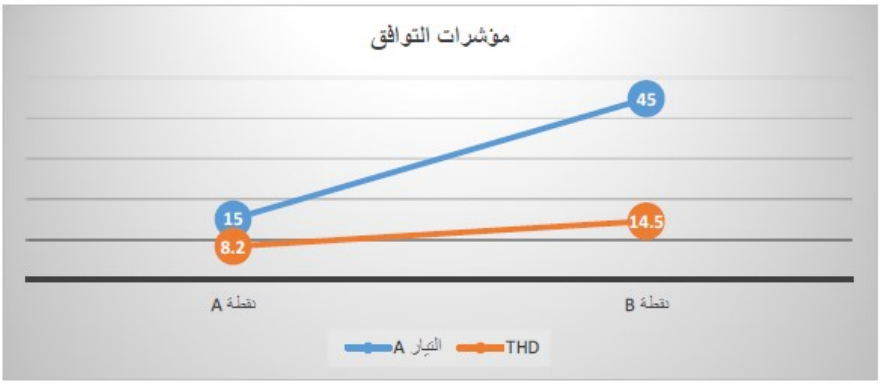

Figure 2: Compatibility indicators in load currents

Analysis of the results from Al-Musayyib district has shown that there is a considerable difference between international standards and the quality of power supplied to consumers. Data show voltage drops are not only a result of overloading, but also directly affected by high impedance of old transmission lines. It has been demonstrated in simulations that significant part of the increased harmonic distortions is due to non-linear loads, which results in higher temperatures in the transformer and corrosion on the insulators.

When compared to earlier research, it is noted that the efficiency of electric motors decreases up to 15% when the voltage fluctuates, this is the reason for the many failures of equipment in the judiciary. The use of harmonic filters can restore system stability to acceptable limits within the specifications as suggested in the discussion. The results of the field data and modelling support the definition of the distribution of capacitor banks at critical load points rather than just adding transformer capacity to the network. This analysis not only helps to elucidate the direct link between power quality and equipment's life, but also offers a technical direction for network development, and can also help to reduce the economic burden on consumers and operators by reducing the energy loss in the form of heat.

Conclusion

The result of this study indicated that the most critical problems causing power networks' failure to deliver the required power quality are electrical fluctuation and frequent voltage drops, which can be identified by the field analysis, and the mathematical modeling of power distribution networks in Al-Musayyib district was achieved. The results showed that the power enhancement capacitors distributed at the critical load points can cause a significant decrease in technical losses and increase the efficiency of the system to approach the impact level. Hence, a practical and comprehensive roadmap has been provided to the decision makers for improving the reliability of the local grid and without damaging the investments made by the consumers so as to achieve the objectives of the study of power distribution in similar environment.

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