**ELECTRIC POWER QUALITY**

CASE STUDY

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Title: Analysis of Power Quality Issues in Different Types of Household Applications: A Case Study

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This case study investigates the power quality issues associated with non-linear loads commonly found in household applications. A laboratory setup is used to examine the performance of different load combinations, including lights, fans, and drive systems. The study focuses on monitoring and analysing unbalanced supply voltages, supply currents, frequency variations, power factor reduction, and total harmonic distortion for both currents and voltages. The findings from the laboratory setup are then compared to a real-time system consisting of an Amada-AE2510NT turret punch CNC machine with multiple single-phase AC servo motors. The dominant power quality issue identified is current harmonics, which are mitigated using shunt active power filters. The effectiveness of the compensation technique is validated through simulation in MATLAB and hardware implementation.

Power quality issues arise due to non-linear loads, such as programmable logic controllers, arc furnaces, welding machines, variable speed drives, and digital storage devices commonly used in both industrial and residential applications. Household appliances like air conditioners, geysers, washing machines, and refrigerators are particularly susceptible to disturbances like harmonics, voltage sag, and voltage swell. These power problems can lead to equipment failure or malfunctions. Therefore, this research aims to address the issue of harmonics, which poses a risk to expensive appliances, by proposing an active power filter as a solution. The study provides a systematic approach that can be understood by individuals with an intermediate level of knowledge in electrical and electronics.

The proliferation of power electronic devices in various sectors, including residential applications, has further exacerbated power quality issues. These devices introduce non-linearity into the system and contribute to the generation of harmonics and reactive power demand. To achieve maximum efficiency and meet international power quality standards, it is crucial to maintain clean power with a pure sinusoidal supply voltage. Power electronic converters and related equipment, such as switched-mode power supplies, varying frequency devices, and electronic ballasts, are known sources of dominant harmonics. These harmonics can cause monetary losses, equipment overheating, and nuisance tripping. As a result, there is a growing interest in power quality issues and compensation techniques.

The research focuses on analyzing power quality issues in both residential load systems and a real-time setup involving a turret punch CNC machine with multiple single-phase AC servo motors. The laboratory setup comprises different combinations of loads, including light loads, fan loads, AC drive systems, and DC drive systems. The power quality parameters monitored include source voltage, source current, fundamental supply frequency, power factor, and total harmonic distortion of voltage and current. The real-time setup involves monitoring the variations in voltage, current, frequency, power factor, and total harmonic distortion during different processes of the CNC machine.

Analysis of Power Quality Issues

The laboratory setup experiment reveals unbalanced source voltages when different loads are connected to the power system. The voltage varies depending on the load combinations, indicating voltage imbalance. Similarly, the real-time servo motor systems in the CNC machine exhibit variations in source voltage due to different processes. The source current also experiences unbalance in the laboratory setup, particularly in the presence of light and fan loads with AC and DC drive systems. However, the unbalance is less pronounced for drive loads. The real-time servo motor systems exhibit more significant variations and unbalance in the source current. Frequency variations occur in both setups, but they remain within the IEEE standards. The power factor shows variations and unbalance in different load conditions, with values ranging from 0.05 to 0.95.

Analysis of Power Quality Issues in Real-Time Setup for Different Load Conditions

In this section, the focus shifts to analyzing power quality issues in a real-time setup, particularly in the Amada-AE2510NT turret punch CNC machine that incorporates multiple single-phase AC servo motor drive systems. This machine is widely used in industries for various processes such as forming, deburring, slotting, and fine contouring.

The objective is to monitor and assess the variations and unbalances in the three-phase supply system, including voltage, current, frequency, power factor, and total harmonic distortion of voltage and current on the source side. The CNC machine operates with individual single-phase AC servo motors, each performing a specific process.

To conduct the analysis, experiments were carried out on the real-time punch machine, and data regarding voltage, current, and other parameters were recorded using the Fluke 434 Series II Energy Analyzer. The real-time data was then transferred to a computer for further analysis. The results obtained from different load conditions were investigated, and a selective resonance filter (SRF) control technique was employed to rectify the identified power quality problems.

Voltage Analysis

The source-side voltage profiles for different load combinations in the real-time setup were observed. Fig. 1 illustrates the variations in the three-phase source voltage, highlighting the unbalanced nature of the voltage, irrespective of the non-linear loads connected to the power system. Each load was switched on at different time periods, and the voltage varied accordingly. The graph shows that the voltage in all three phases is not the same, indicating an unbalanced condition.

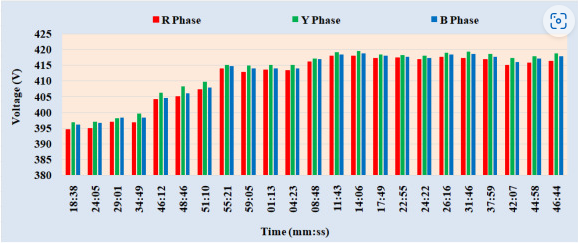


Fig. 1

Fig. 2 further showcases the source voltage profiles of the real-time servo motor systems while performing different processes. The voltage variations occur based on the specific operation of the single-phase AC servo motors. It is evident from the graph that the voltage is not consistent across all three phases, with peak values ranging from 398 V to 408 V.

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Fig. 2

Current Analysis

The variations and unbalance in the three-phase source current were analyzed for different load conditions and real-time servo motor systems. Fig. 3 and Fig. 4 depict the observed variations. In the laboratory setup, the unbalance in current is more pronounced for the light and fan loads with the AC and DC drive systems. The unbalance in three-phase current is found to be more severe compared to the unbalance in three-phase voltage when the system is connected to residential non-linear loads. The maximum recorded current for these loads is 8 A.

Similarly, in the real-time setup, the variations and unbalances in current are more significant due to the diverse functions of the CNC machine. The maximum recorded current for these loads is 13 A.

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Fig. 3

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Fig. 4

Frequency and Power Factor Analysis

The frequency variations were analyzed for different load conditions and real-time systems. The graphs in Fig. 5 and Fig. 6 illustrate the observed variations. The fundamental frequency was found to range from 49.925 Hz to 50.152 Hz, which falls within the IEEE standards.

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Fig. 5

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Fig. 6

Furthermore, the power factor variations were analyzed, as shown in Fig. 7 and Fig. 8. The recorded power factor ranged from 0.05 to 0.95, with the maximum power factor of 0.75 appearing in the majority of events. These variations in power factor indicate the impact of different load conditions and operating states on the power quality.

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Fig. 7

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Fig. 8

Overall, the analysis of power quality issues in the real-time setup provided valuable insights into the variations and unbalances in voltage, current, frequency, and power factor. These findings contribute to a better understanding of the power quality challenges faced in industrial settings, particularly in the presence of non-linear loads such as AC servo motors.

Mitigation Techniques: Shunt Active Power Filters

To address the dominant power quality issue of current harmonics, shunt active power filters (SAPFs) are proposed as a viable mitigation technique. SAPFs are capable of compensating for the harmonic currents generated by non-linear loads, thus ensuring a cleaner power supply with reduced harmonic distortion.

The SAPFs employ advanced control algorithms to detect the harmonic components in the source current and generate compensating currents to eliminate or minimize the harmonics. This technique effectively mitigates the adverse effects of harmonics, such as equipment overheating, voltage distortion, and malfunctions.

To validate the effectiveness of SAPFs, simulations were conducted using MATLAB/Simulink. The simulation results confirmed the successful reduction of harmonic currents and the improvement of power quality parameters such as total harmonic distortion (THD) and power factor.

Furthermore, the proposed SAPF technique was implemented in the laboratory setup and the real-time CNC machine. The hardware implementation involved the installation of SAPF units connected in parallel with the load systems. The real-time measurements demonstrated a significant reduction in harmonic currents and improved power quality, thereby validating the efficacy of SAPFs as a mitigation technique.

Conclusion

In conclusion, this case study analyzed power quality issues associated with non-linear loads in household applications and industrial setups. The investigations conducted in both the laboratory setup and the real-time CNC machine revealed variations and unbalances in voltage, current, frequency, and power factor.

The dominant power quality issue identified was current harmonics, which can lead to equipment malfunctions and financial losses. To mitigate this problem, shunt active power filters (SAPFs) were proposed as an effective solution. The simulation and hardware implementation results validated the effectiveness of SAPFs in reducing harmonic currents and improving power quality parameters.

This research provides valuable insights into the power quality challenges faced in different load conditions and emphasizes the importance of implementing appropriate mitigation techniques to ensure a reliable and efficient power supply. By addressing power quality issues, this study contributes to the overall enhancement of equipment performance, longevity, and customer satisfaction in both residential and industrial sectors.