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Performance and Analysis of Fuzzy Logic Controller Based Power Quality Monitoring and Improvement System.

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Abstract

Power quality is an issue that necessities ceaseless consideration and has progressively been utilized as the key pointer for benchmarking of the genuine execution of numerous electrical utilities. Since nature of voltage holds huge significance in the usefulness of any power system, checking of voltage quality has turned into a noteworthy territory of examination. The extraordinary budgetary weight required may not be ideal to give estimations at each bus and line in a system in both transmission and distribution levels. Be that as it may; to settle on the remedial measures, it is basic to recognize the sort and the area of the blame in a power system. In this thesis artificial intelligence-based power monitoring and improvement system has been discussed. Monitoring and controlling of power quality is imperative to ensure power quality. Mishaps regularly happen in view of awful power supply quality. So, Government body and client of electric power all need to enhance control of power quality. Monitoring and analysis System of power quality is widely utilized. Checking based on LabVIEW is produced in this investigation. Different power quality parameters like Voltage, Current, Voltage THD, Current THD, Active power, Apparent power, Reactive power, Power factor, Active energy, Reactive energy, apparent energy, THD after improvement etc. has been continuously monitored in this project.

Keywords: *Power Quality, Active-Reactive Power, Fuzzy Logic Controller (FLC), Total Harmonic Mitigation (THD).*

1. Introduction

Monitoring and improvement of power quality is required in power system for better execution, supervision and control over the power system and related equipment. Power quality is defined as to get perfectly sinusoidal voltage having 50 Hz and 220V (or standard voltage as per requirement) uninterrupted power supply to the customers. The power quality depends on lot of parameters like harmonics, noise, voltage and current fluctuations, phase, fundamental frequency etc. Power quality monitoring devices are very costly and power quality improvement is also very cumbersome job. The good power quality must be maintained for proper functioning of electrical equipment. There are many methods used for power quality improvement. However, this paper uses filters to improve the power quality.[1-4] The NI LabVIEW and Fuzzy Logic Toolkit is an add-on to the LabVIEW graphical development environment that can be used to add sophisticated fuzzy control algorithms to LabVIEW programs. The NI LabVIEW Electrical Power Suite helps to develop a custom single- or three-phase power monitoring, metering, or quality analysis application. With the LabVIEW Electrical Power Suite, one can combine the fixed standardized algorithms from the power industry with the custom capability of a full programming language and modular hardware.[5-8] The analysis functions included with this suite are Power frequency, Magnitude of the supply voltage, Supply voltage dips/swells, Voltage interruptions, Supply voltage unbalance, Measurement of under-deviation and over-deviation parameters, Voltage harmonics & Mains signalling voltage on the supply voltage.[9-12] To address these challenges, intelligent control techniques have gained considerable attention. Among them, Fuzzy Logic has emerged as a powerful tool due to its ability to handle uncertainty, nonlinearity, and imprecise inputs without requiring an exact mathematical model of the system.[13-15] Power quality disturbances such as voltage sags, swells, harmonics, flicker, and interruptions can lead to malfunctioning of equipment, reduced efficiency, and economic losses. With the expansion of nonlinear loads and power electronic devices, these disturbances have become more frequent and complex, making conventional monitoring and mitigation techniques less effective. In a power quality monitoring and improvement system, real-time measurement and analysis of electrical parameters such as voltage and current are essential for detecting disturbances. Once identified, appropriate corrective actions must be implemented promptly to maintain system stability and performance. The integration of an FLC with power electronic compensating devices, such as Dynamic Voltage Restorers (DVR), Active Power Filters (APF), and STATCOMs, provides an effective solution for mitigating power quality issues. The FLC processes error signals and generates suitable control actions to compensate for disturbances, ensuring improved voltage profiles and reduced harmonic distortion. This study focuses on the performance and analysis of a fuzzy logic controller-based power quality monitoring and improvement system. It evaluates the effectiveness of the proposed approach in detecting and mitigating various power quality disturbances under different operating conditions. The system's performance is analysed based on key parameters such as response time, Total Harmonic Distortion (THD), and voltage stability. The results demonstrate that the FLC-based approach offers superior adaptability, faster response, and enhanced performance compared to conventional control methods. Overall, the implementation of fuzzy logic in power quality enhancement systems presents a promising solution for modern power networks, contributing to improved reliability, efficiency, and stability in increasingly complex electrical environments.Top of Form Bottom of Form

2. System Configuration

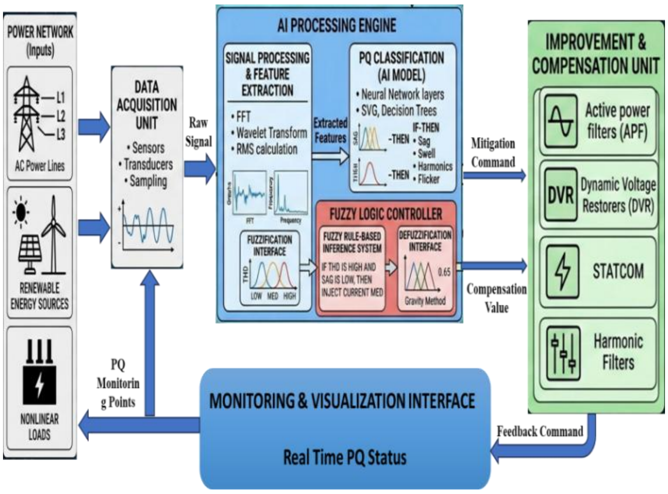

Figure 1 Block Diagram of AI Based Power Quality Monitoring & Improvement System

Block diagram of proposed system shown in Fig. 1, which describes that fuzzy systems have been broadly used for a wide engineering application. Especially, it has been successfully applied in control systems and decision-making systems.

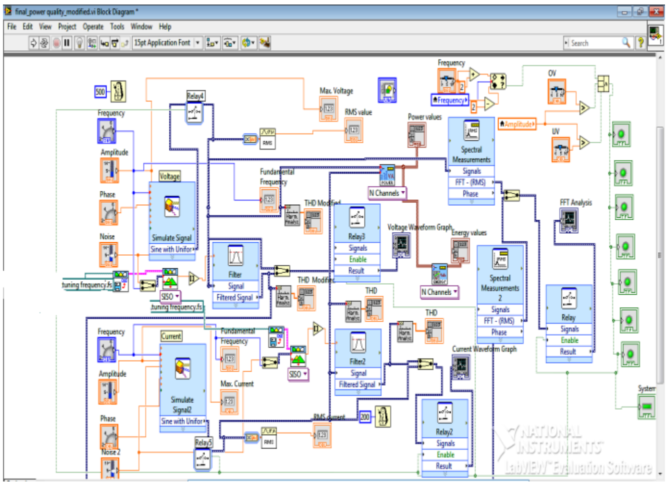

Figure 2 Circuit Diagram of AI Based Power Quality Monitoring & Improvement System Using Lab View

There are different sections in the proposed system as shown below in Fig. 2 describes the different sections in power quality like Voltage section, Current section, Current wave form graph, Voltage wave form graph, FFT analyser, Power values Energy values, Current parameter, Voltage parameter etc.

3. Mathematical Modelling

Active Reactive Power (p-q) Theory: 3-phase instantaneous supply voltage is changed into 2-phase orthogonal voltage signals (vα, vβ) using Clark's transformation;

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

Clark transform is utilized to 3-phase load current. Orthogonal factor of load current (ilα, ilβ) is stated as;

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix}$$

Equating real and imaginary part of active and reactive power are derived as;

$$p = v_\alpha i_{l\alpha} + v_\beta i_{l\beta}$$

$$q = v_\alpha i_{l\beta} - v_\beta i_{l\alpha}$$

For harmonic compensation, total power

$$p_t = p_{ac} + p_{loss}$$

So instantaneous active and reactive power is assigned as in matrix form;

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_{c\alpha}^* \\ i_{c\beta}^* \end{bmatrix}$$

So reference orthogonal factors of current can be obtain as-

$$\begin{bmatrix} i_{c\alpha}^* \\ i_{c\beta}^* \end{bmatrix} = \frac{1}{\sqrt{v_\alpha^2 + v_\beta^2}} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_t \\ q \end{bmatrix}$$

3-Phase reference supply current ($i_{sa}^*, i_{sb}^*, i_{sc}^*$)is characterized as;

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 0 & 1 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha}^* \\ i_{c\beta}^* \end{bmatrix}$$

4. Simulations and Results

Proposed architecture performance has been assessed through Lab-view /Simulink. System performance is tested out under balanced voltage Condition with nonlinear load. Proposed scheme has been exercised to reduce harmonic. Fig. 3 and Fig. 4 show inputs of Fuzzy controller. Output surface view is displayed in Fig. 5 Fuzzy surface can be observed in Figure 6.

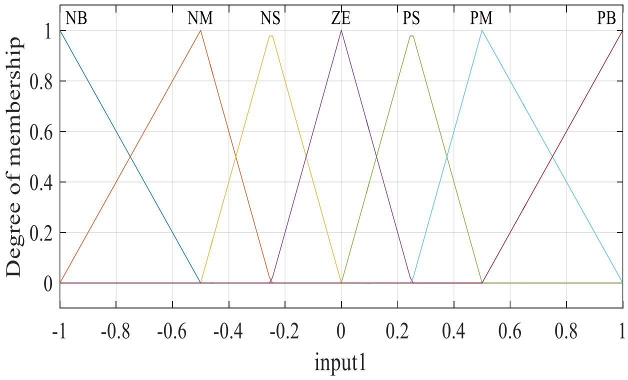

Figure 3 **Membership Functions For Input 1**

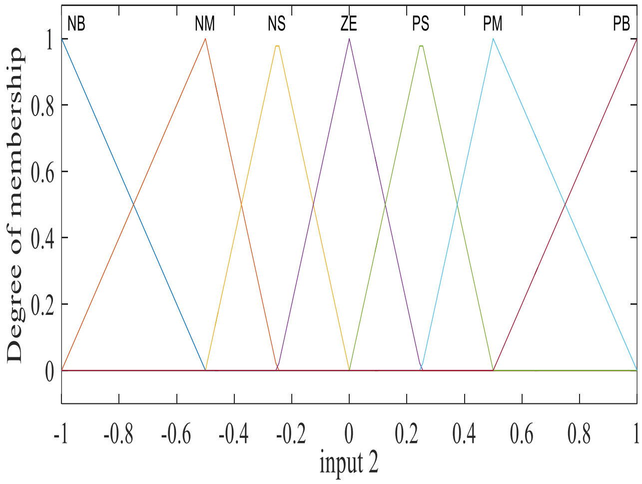

Figure 4 **Membership Functions for Input 2**

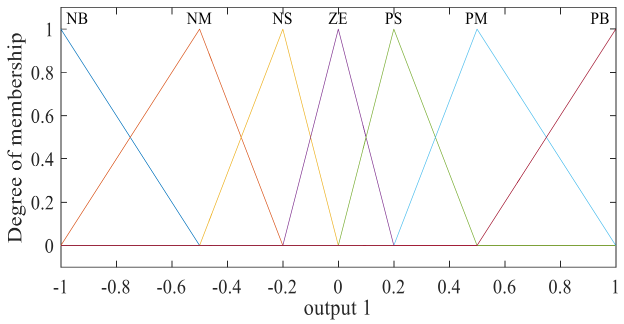

Figure 5 Membership Functions for Output 1

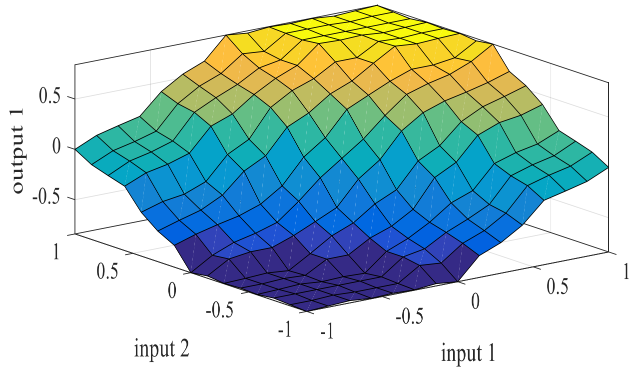

Figure 6 Fuzzy Surface View

Three phase source compensated current have been exemplified in Figure 7 along with active power with balance supply voltage in Figure 8 and Figure 9 reactive power with balance supply voltage in respectively. Corresponding FFT analysis of balance supply voltage is about 3.05% shown in figure 10.

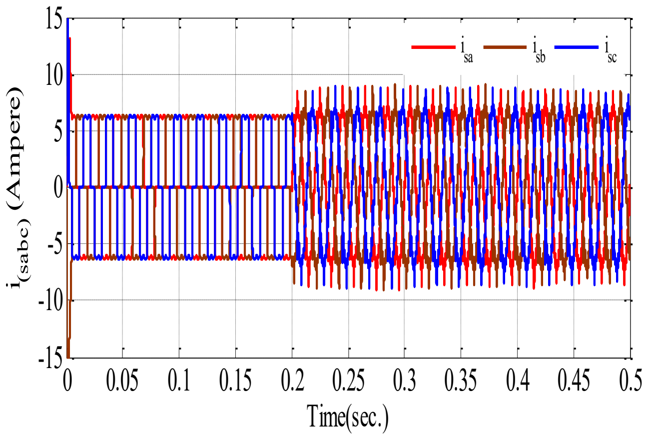

Figure 7 Performance of Fuzzy Logic Controller with Compensated Current

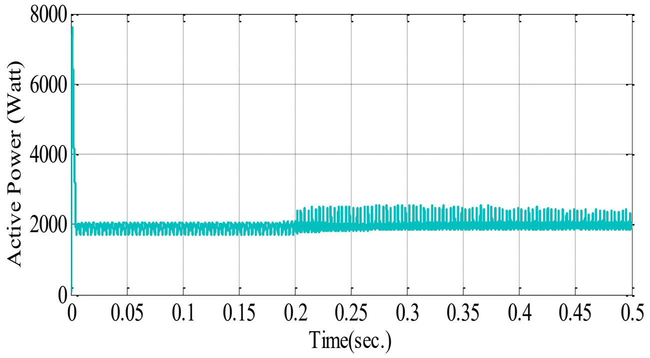

Figure 8 Active power with balance supply voltage

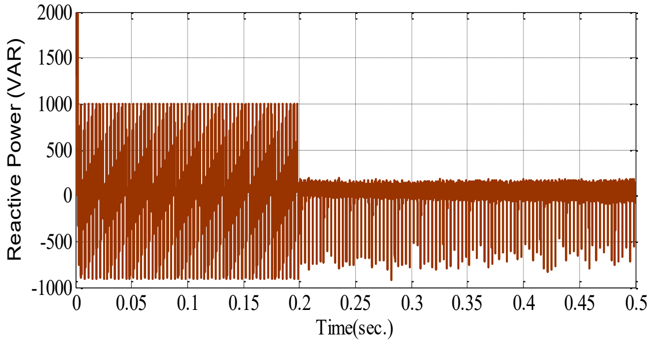

Figure 9 Reactive power with balance supply voltage

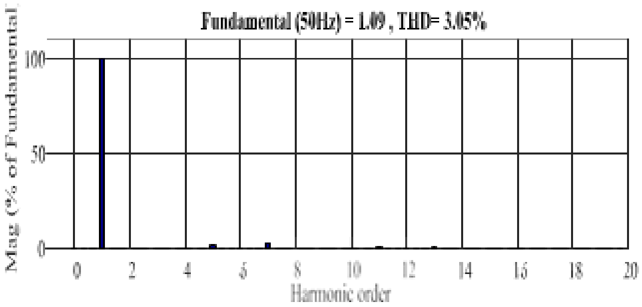

Figure 10 FFT analysis after compensation with balance supply voltage

Conclusion

AI-Fuzzy Logic framework transforms Power Quality management from a reactive "detect-and-fix" process into a proactive, autonomous optimization engine. This synergy ensures a stable, "clean" power supply that is essential for the sensitive digital equipment and automated industries of the modern era. As grids become more complex, the ability of Fuzzy Logic to mimic human-like reasoning will remain a cornerstone in achieving global energy efficiency and reliability.

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