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Optimizing Power Quality in Star Connected Distribution System By Using D-Statcom

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ABSTRACT: The primary causes of power quality issues stem from supply failures and unbalanced loads. These issues manifest as voltage fluctuations, deformations, flickers, unbalances, sags, and expansions at the point of common coupling. In 3-phase 4-wire power distribution systems, additional problems arise from capacitor bank failures, noise, vibrations, and the operation of induction motors. This article outlines the utilization of DSTATCOM for enhancing power quality in such systems. A PI controller based on synchronous reference frame theory (SRFT) is implemented in this study to address power quality concerns. The key aim is to mitigate voltage-related power quality issues, and the reduction of harmonics within the three-phase distribution supply.

KEYWORDS: Power quality issues, distribution network, voltage dips, voltage surges, and flickering., Harmonics mitigation, System reliability, Sinusoidal Pulse Width Modulation (SPWM).

I. INTRODUCTION

The term "power quality" may seem straightforward, but it encompasses a range of issues present in any electrical power system. Moreover, what constitutes "good" or "bad" power quality is subjective and dependent on the individual user's experience. If electrical equipment operates smoothly, users perceive the power quality as satisfactory. However, if equipment malfunctions or fails prematurely, users deem the power quality as poor. Within this spectrum, there exist various grades or levels of power quality, shaped by the perspectives of different users.

Recognizing and understanding power quality issues is crucial for addressing any related problems effectively. It serves as a fundamental starting point for troubleshooting and resolving issues within electrical systems, ensuring optimal performance and reliability. In-depth exploration has been conducted on several advanced control methods aimed at enhancing power quality, particularly focusing on the reduction of harmonics in distribution supply. These sophisticated techniques are pivotal in addressing power quality issues by effectively mitigating harmonics, thereby improving the overall performance of electrical systems.

Notably, inverters play a significant role in power quality improvement, particularly within Dynamic Static Compensator (DSTATCOM) circuits. These inverters are instrumental in regulating voltage and current waveforms, thereby enhancing system stability and minimizing harmonic distortion on the distribution supply side. Their integration into DSTATCOM circuits underscores their importance in achieving optimal power quality and ensuring reliable operation of electrical networks. Advanced multilevel inverter circuits with reduced device counts have been developed, accompanied by sophisticated control algorithms, aiming to improve performance while minimizing component requirements. These innovations offer cost-effective and efficient solutions for power conversion systems by achieving higher voltage levels, lower harmonic distortion, and precise regulation of voltage and current waveforms. In enhancing microgrid power quality, a pioneering technique utilizing fuzzy logic was applied, as described in reference. The authors successfully implemented a DSTATCOM with reduced device count, effectively improving power quality within the distribution grid.

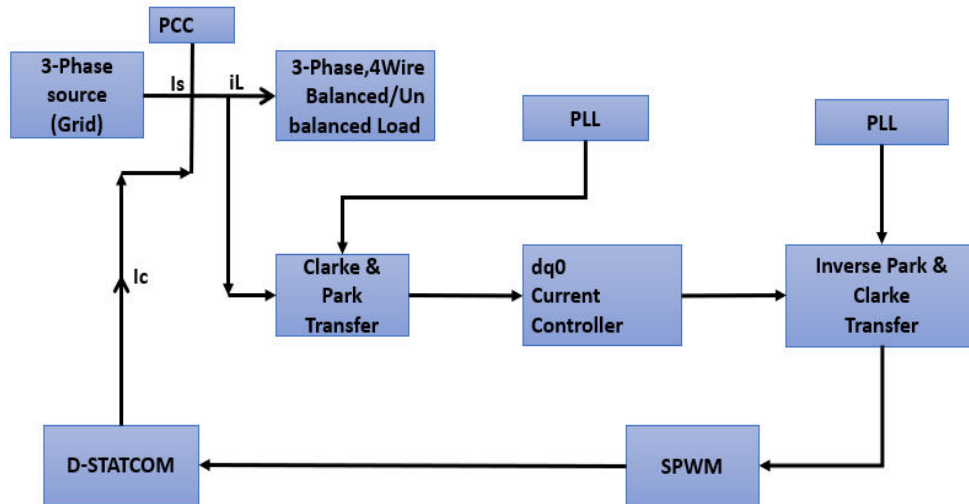


Fig.1. Block diagram of power quality star connected distribution system by using D-STATCOM

This innovative approach aims to mitigate power quality issues by employing a fuzzy logic-based control strategy tailored for microgrid applications. Specifically, the technique optimizes DSTATCOM performance while minimizing the number of components required, thus reducing cost and complexity. By integrating fuzzy logic principles, the control algorithm enhances the DSTATCOM's ability to compensate for reactive power, harmonics, and voltage fluctuations. The reduced device count aspect further enhances the system's efficiency and reliability while achieving significant improvements in power quality metrics. This methodology represents a significant advancement in microgrid power quality enhancement, offering a practical and effective solution for addressing grid stability and reliability challenges. A grid-connected PV system on the distribution side saw enhanced power quality through the implementation of an Adaline-based least mean square algorithm.

This algorithm effectively improved power quality, especially during non-linear load durations, showcasing its robust performance. The system's operation demonstrated notable efficacy in mitigating power quality issues, indicating its suitability for real-world applications.

II. RECENT WORKS

Recent research has focused on optimizing control strategies for D-STATCOMs to enhance their performance in 3-phase 4-wire distribution systems. Advanced control algorithms, such as model predictive control (MPC) and fuzzy logic control, are being investigated to improve voltage regulation and mitigate harmonics effectively.

Hybrid solutions combining D-STATCOMs with other custom power devices, such as active power filters (APFs) or energy storage systems (ESS), are gaining attention. These hybrid configurations offer improved flexibility and performance in addressing various power quality issues simultaneously, including voltage sag/swell mitigation and harmonic suppression.

Standardization efforts aimed at ensuring interoperability and compatibility of D-STATCOMs with existing distribution system infrastructure are ongoing. Recent research emphasizes the development of standardized communication protocols and interfaces to facilitate seamless integration of D-STATCOMs into 3-phase 4-wire distribution systems.

III. PROPOSED WORK

A. SPWM:

Sinusoidal Pulse Width Modulation (SPWM) is a modulation technique used in power electronics to synthesize AC waveforms from a DC source. It works by generating a series of pulses whose widths vary sinusoidally according to a reference waveform, typically a sine wave. These modulated pulses are then applied to a power electronic switching device, such as an inverter, to produce an output waveform that closely resembles the desired sinusoidal waveform.

In SPWM, the width of each pulse is determined by comparing the instantaneous value of the reference sinusoidal waveform with a carrier waveform, usually a high-frequency triangular or sawtooth waveform. The comparison is typically done using a comparator or a similar device.

When the instantaneous value of the reference waveform is greater than the carrier waveform, the pulse width is set to a high value, and when it is less, the pulse width is set to a low value. This process repeats at a high frequency, resulting in a series of modulated pulses whose average value closely follows the reference waveform.

SPWM offers several advantages, including low harmonic distortion, simplicity of implementation, and compatibility with digital control techniques. It is widely used in applications such as motor drives, uninterruptible power supplies (UPS), and grid-connected inverters for renewable energy systems.

B.D-STATCOM:

D-STATCOM is a modern power electronic device used for power quality improvement in distribution systems. It operates by injecting reactive power dynamically to regulate the voltage at the point of common coupling (PCC), thereby mitigating voltage fluctuations and improving power factor.

The primary function of a D-STATCOM is to provide reactive power compensation instantaneously to counteract any variations in the load or supply conditions. It achieves this by controlling the output voltage of an inverter connected in parallel with the distribution system.

The control strategy of a D-STATCOM involves sensing the voltage and current at the PCC and using this information to generate appropriate control signals for the inverter. These control signals adjust the output voltage of the inverter to inject or absorb reactive power as needed to maintain the desired voltage level and power factor at the PCC.

One common control method used in D-STATCOMs is the voltage-source converter (VSC) based control. This involves generating reference voltage signals based on the desired voltage at the PCC and comparing them with the actual voltage measurements. The difference between the reference and actual voltages is used to generate control signals for the inverter.

MATLAB is a widely used tool for simulating and designing D-STATCOM systems. Engineers can use MATLAB's Simulink and Simscape Power Systems toolboxes to model the D-STATCOM components, including the VSC-based control system, and simulate its operation under various operating conditions.

3.1 Mathematical Expressions and Symbols

C. Clark Transform:

The Forward Clark Transform is a mathematical operation used in electrical engineering and power systems, particularly in the analysis of three-phase alternating current (AC) systems.

Three phase quantities are converted into the two coordinate systems i.e. alpha and beta. Above formula is used for conversion. This transformation simplifies the analysis and control of AC systems.

$$\alpha(t) = \frac{2}{3}a(t) - \frac{1}{3}b(t) - \frac{1}{3}c(t) \tag{1}$$

$$\beta(t) = \frac{1}{\sqrt{3}}b(t) - \frac{1}{\sqrt{3}}c(t) \tag{2}$$

Above formulas are used for conversion.

D.Inverse Park Transform:

Three phase quantities are converted into the two coordinate systems i.e. alpha and beta. Above formula is used for conversion. This transformation simplifies the analysis and control of AC systems. The Forward Clark Transform is a mathematical operation used in electrical engineering and power systems, particularly in the analysis of three-phase alternating current (AC) systems

It is the inverse operation of the Park Transform is commonly employed in the control of three-phase alternating current (AC) systems, particularly in applications such as motor control and power electronics. The Inverse Park Transform converts the coordinates back from the dq reference frame to the ABC reference frame. The equations for the Inverse Park Transform are as follows: Let θ represent the electrical angle.

Given the dq components V_d and V_q , the inverse Park Transform yields the corresponding α, β components V_α, V_β as follows:

$$V_\alpha = V_d \cos\theta - V_q \sin\theta \tag{3}$$

$$V_\beta = V_d \sin\theta + V_q \cos\theta \tag{4}$$

To address harmonics and power quality concerns, the load currents from a 3-phase 4-wire grid are converted to 2-phase using Clarke-Park transformations. This process involves utilizing a phase-locked loop (PLL) for the conversion from 3-phase to 2-phase. Subsequently, the transformed currents are directed to a current controller to achieve the desired d-q currents necessary for operation. Finally, the obtained d-q currents undergo an Inverse Park-Clarke transformation to ensure distortion-free and harmonic-free currents are obtained for improved power quality.

Once the resultant currents from the controller are obtained, they are fed into the Sinusoidal Pulse Width Modulation (SPWM) technique, which generates pulse signals. These pulse signals serve as inputs to the DSTATCOM, where the inverter generates compensating currents (AC). These compensating currents are then injected at the point of common coupling (PCC) to mitigate power quality issues.

In the event of harmonics or ripples in the currents, the same process described above is repeated iteratively. This iterative loop ensures that any deviations from the desired load currents are promptly identified and corrected, maintaining the stability and quality of the power supply. This iterative feedback mechanism allows for continuous monitoring and adjustment, ensuring that the system effectively addresses power quality concerns and provides reliable operation.

Various solutions for addressing these voltage and current-related power quality problems include DSTATCOMs, DVRs, and UPQCs. In particular, Fig 2 illustrates the utilization of DSTATCOMs as a solution for current-based power quality issues. Fig 3 demonstrates how DSTATCOMs compensate for reactive power, balance loads, minimize neutral currents, and mitigate current harmonics, thereby enhancing overall power quality.

4. Arrangement Of D-Statcom In Matlab

In MATLAB, the arrangement of a Distribution Static Synchronous Compensator (DSTATCOM) involves several key steps to enhance power quality. Firstly, the DSTATCOM structure is defined, typically including a Voltage Source Inverter (VSI), which is pivotal for generating compensating currents. Park and Clark transformations are then applied to convert the 3-phase grid currents into a 2-phase reference frame, facilitating easier control implementation. This transformation aids in reducing Total Harmonic Distortion (THD) by

effectively managing harmonics and improving system stability. Next, the control algorithm for DSTATCOM operation is developed. This algorithm governs the VSI to produce compensating currents in response to grid voltage and current measurements. Popular control techniques such as PI control or advanced control strategies like Model Predictive Control (MPC) may be implemented to ensure efficient performance.

4.1. Arrangement Of Spwm In Matlab

Sinusoidal Pulse Width Modulation (SPWM) is a modulation technique used in power electronics to synthesize AC waveforms from a DC source. It works by generating a series of pulses whose widths vary sinusoidally according to a reference waveform, typically a sine wave. These modulated pulses are then applied to a power electronic switching device, such as an inverter, to produce an output waveform that closely resembles the desired sinusoidal waveform.

In SPWM, the width of each pulse is determined by comparing the instantaneous value of the reference sinusoidal waveform with a carrier waveform, usually a high-frequency triangular or sawtooth waveform. The comparison is typically done using a comparator or a similar device.

In MATLAB, SPWM can be implemented using built-in functions for signal generation and modulation, as well as control system design and simulation tools. By simulating SPWM in MATLAB, engineers can analyze and optimize the performance of power electronic systems before hardware implementation, saving time and cost in the development process.

V. SIMULATION PARAMETERS

S.no	Parameter Name	Component Value
1	Source side voltage	230v, 50HZ
2	Load parameters	R=100ohm & L= 10e-3 Henry
3	DC link capacitor	500V & 3650e-6
4	Source side impedance value	R=0.1 & L=0.1e-3Henry

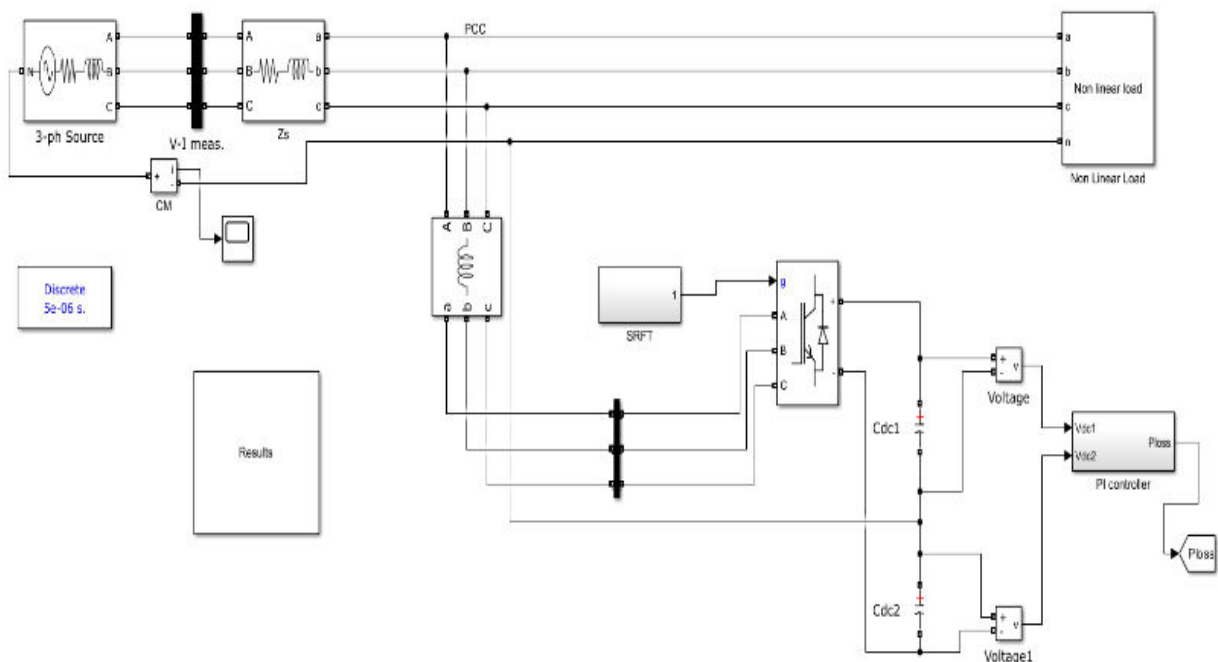


Fig.2.Simulink for star connected distribution system

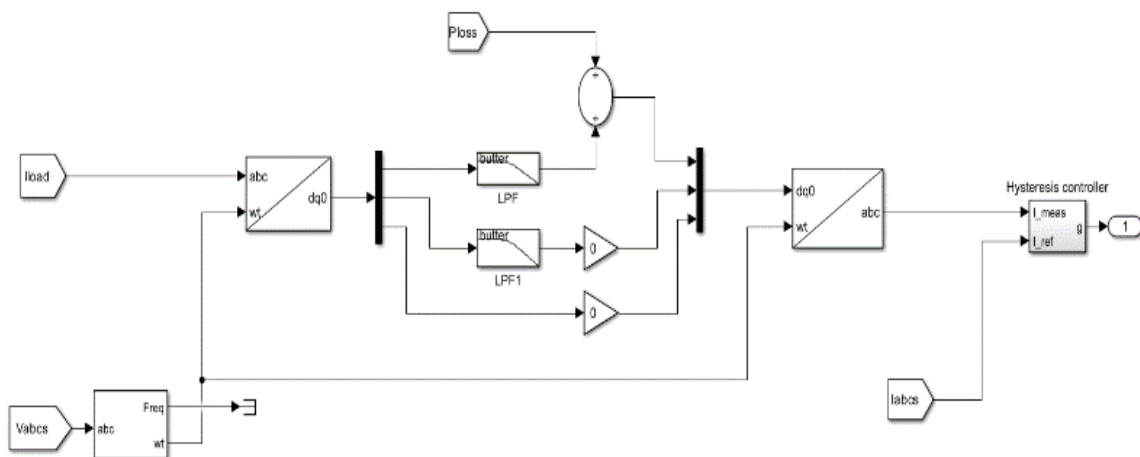


Fig.3.Synchronous Frame Rotating Theory

Synchronous Frame Rotating Theory (SFRT) is a fundamental concept utilized in power systems engineering for analyzing and controlling the behavior of synchronous machines like generators and motors.

At its core, SFRT involves transforming the mathematical description of electrical quantities, such as voltage and current, from a stationary reference frame to a rotating reference frame synchronized with the electrical frequency. This transformation simplifies the analysis and control of synchronous machines by aligning the electrical quantities with the rotor motion.

The essence of SFRT lies in performing coordinate transformations, typically employing the Park and Clarke transformations, to convert three-phase quantities into a two-dimensional

representation in a rotating reference frame. In this frame, the direct axis (d-axis) aligns with the rotor flux, while the quadrature axis (q-axis) is orthogonal to it.

Overall, SFRT serves as a powerful tool in power system analysis and control, enabling engineers to design and implement sophisticated control strategies for synchronous machines, thereby improving overall system performance and reliability.

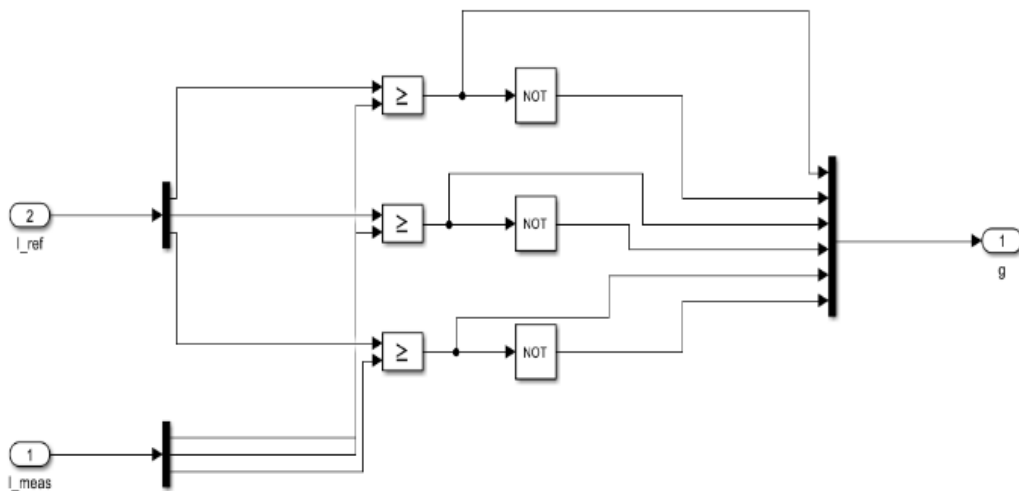


Fig.4.Hysteresis controller

Implementing a hysteresis controller in MATLAB involves creating a control algorithm that generates switching signals based on the error between the reference signal and the actual system output. Here's a simplified example of how you might implement a hysteresis controller in MATLAB.

Finally, we use the output for system control or simulation. This could involve applying the output to a system model and observing the system response.

This example provides a basic implementation of a hysteresis controller in MATLAB. Depending on your specific application and requirements, you may need to modify the parameters and logic of the controller accordingly.

VI. RESULTS AND DISCUSSION



Fig.5. Three-phasesupplycurrentwaveforms

The three-phase supply currents are characterized by equal magnitudes and a 120-degree phase shift between them. Additionally, these phase currents exhibit minimal harmonic distortion.



Fig.6.Three-phase load current waveforms

This waveforms are giving to the grid supply to non linear load side current waveforms. Initial current fed to the conversion of 3-phase to 2-phase.

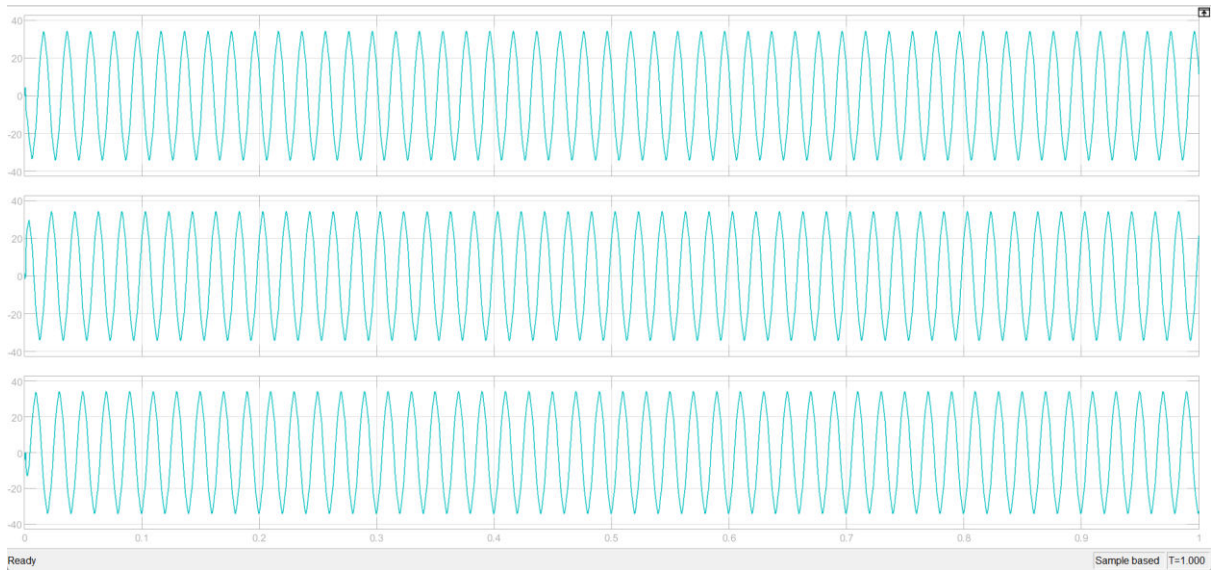


Fig.7.Three-phase compensating current waveforms

The above fig shows compensating currents after reduce the harmonics and ripples in distribution system by using D-STATCOM. Get the output waveforms.

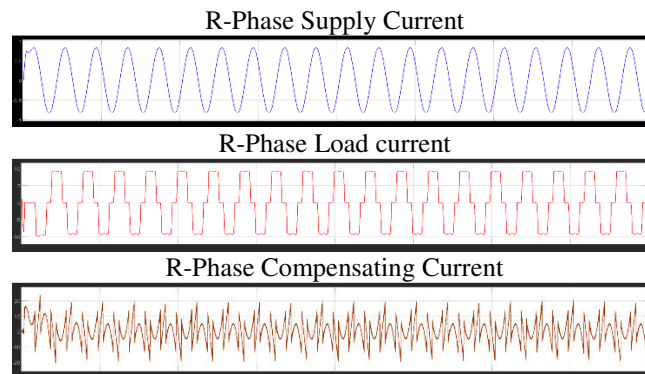


Fig.8.R-phase supply current, load current and compensating current

Figure 6 illustrates the waveforms of three-phase compensating currents, generated by the DSTATCOM circuit. Meanwhile, Figure 8 displays the R-phase supply current, R-phase load current, and R-phase compensating current merged into a single waveform.

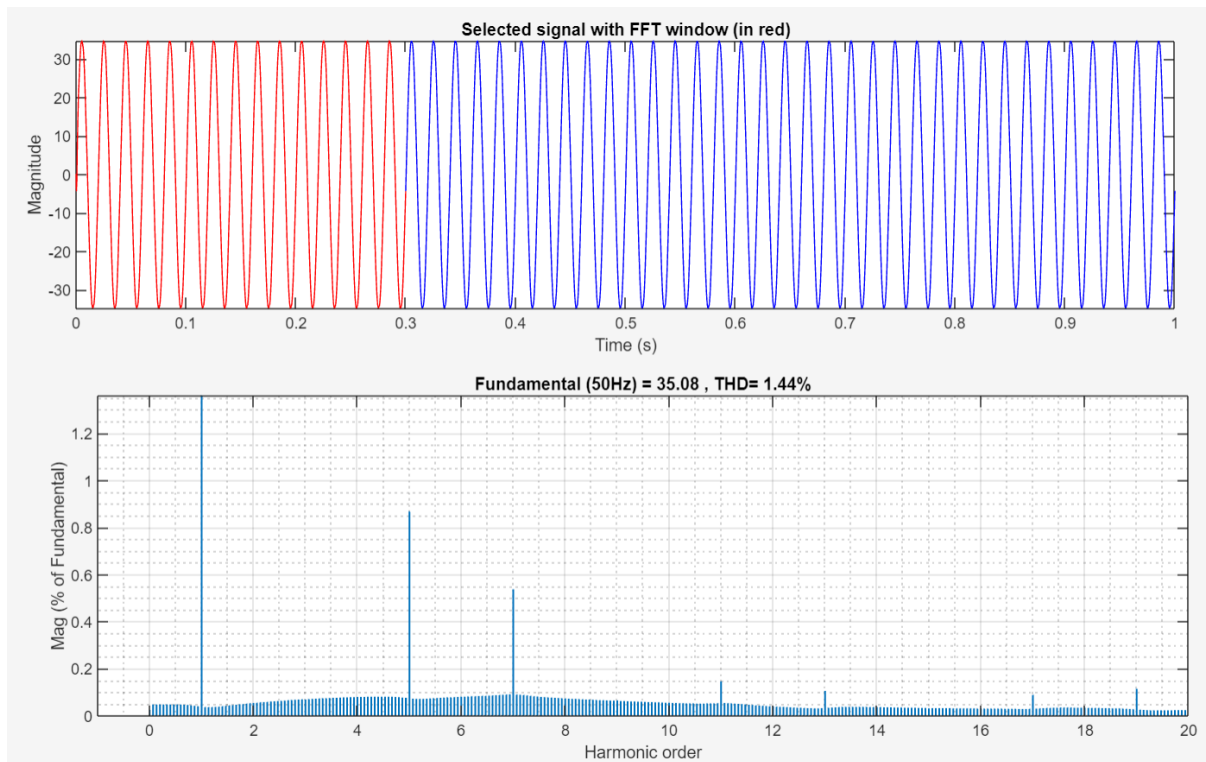


Fig.9. harmonic spectrum for supply current

Fig.9 shows the harmonic spectrum in supply current. The THD value R-phase current is 1.44%. This section summarizes the effectiveness of the three-phase four-wire topology when operating under nonlinear load conditions. The DSTATCOM technique successfully mitigated current harmonics on the supply side and maintained balanced DC link voltage during both balanced and unbalanced periods.

6.1 COMPARISON

EXISTING METHOD	PROPOSING METHOD
<ul style="list-style-type: none"> • Usage of more components makes the system complex and increase in initial cost. • Operation and maintenance is complex. • The power system stability cannot be improved. • Current Source Inverter is used. • Results and analysis • Voltage performance • Harmonic effectiveness • Reactive power compensation 	<ul style="list-style-type: none"> • As the components are less, initial cost is affordable. • Operation and maintenance is easy. • The system stability can be improved. • Voltage Source Inverter is used. • Comparative analysis with 3-wire system • Results interpretation

VII. CONCLUSION

This study conducted simulations on a 3-phase 4-wire distribution system, utilizing a DSTATCOM to enhance power quality within power distribution networks. The implementation includes an SRFT-based PI controller aimed at achieving a unity power factor on the supply side, balancing capacitor voltage, ensuring balanced three-phase supply voltages and currents, as well as balanced load currents and voltages. The system operates effectively under both balanced and unbalanced conditions, with notable results observed in the output voltage and current. It reduces the Total Harmonic Distortion up to 1.44% .



REFERENCES

- [1] Chenchireddy, Kalagotla, et al. "A Review on D-STATCOM Control Techniques for Power Quality Improvement in Distribution." 2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA). IEEE, 2021.
- [2] Chenchireddy, K., & Jegathesan, V. (2021). A Review Paper on the Elimination of Low-Order Harmonics in Multilevel Inverters Using Different Modulation Techniques. *Inventive Communication and Computational Technologies*, 961-971.
- [3] Sydu, Shabbier Ahmed, Kalagotla Chenchireddy, and Khammampati R. Sreejyothi. "Novel PSO-Fuzzy Logic Based Control Method for Unified Power Quality Conditioner (UPQC) for Harmonic Distribution." Available at SSRN 3852706 (2021).
- [4] Kumar, Amit, and Pradeep Kumar. "Power Quality Improvement for Grid-connected PV System Based on Distribution Static Compensator with Fuzzy Logic Controller and UVT/ADALINE-based Least Mean Square Controller." *Journal of Modern Power Systems and Clean Energy* 9.6 (2021): 1289-1299.



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