Power Quality Enhancement in Micro grid System Using PV Based UPQC

Saila Kranthi Kumar[1] Kavali B S R Sai Kumar[2] Gurana Varshitha[3] Rohit Kumar[4]
Vana Karthik[5] Lalam Narendra[6] Chandaka Ravi[7]

Asso.Professor, Department of EEE, Raghu Engg. College, Visakhapatnam, AP, India.[1]
B.Tech Students, Department of EEE, Raghu Engg. College, Visakhapatnam, AP, India.[2,3,4,5,6,7]

Abstract- **Providing high-quality, reliable, and continuous power to consumers is crucial in today's power systems. However, the increasing demand and widespread use of power electronic devices have introduced various power quality issues, including voltage sags, swells, and harmonics. To mitigate these issues, advanced power electronic devices have been employed. This project focuses on utilizing a Unified Power Quality Conditioner (UPQC) integrated with a solar PV array to maintain optimal power quality. The UPQC combines series and shunt compensators, enabling it to perform multiple tasks and improve power quality. The series converter addresses grid-side power quality problems, such as voltage sags and swells, while regulating the load voltage and PCC voltage. Meanwhile, the shunt compensator mitigates current harmonics caused by nonlinear loads, leveraging power from the PV array. A synchronous reference frame control strategy based on a moving average filter generates the reference signal. The UPQC model is developed and simulated using MATLAB/SIMULINK software to evaluate its performance.**

Keywords: Solar PV, UPQC, Power Quality.

I. INTRODUCTION

In the modern distribution system, there has been a significant increase in the adoption of clean energy systems based on solar and wind energy. However, these sources are intermittent, resulting in voltage fluctuations that pose challenges in low voltage distribution systems. Additionally, the use of advanced power electronic systems like computer power supplies, switched-mode power supplies, variable frequency drives, and servers, which are energy-efficient, has become widespread. However, these systems draw highly nonlinear current from the power supply, making them sensitive to voltage disturbances and causing issues such as increased losses in distribution transformers and voltage distortion at the point of common coupling (PCC). To address these challenges, future systems require the integration of clean energy generation with active filtering to improve power quality. This integration not only mitigates power quality problems but also reduces dependence on fossil fuels, leading to a better environmental quality.

The integration of renewable energy with flexible AC transmission systems (FACTS) devices, such as the unified power flow controller (UPFC), has been discussed in the literature. These devices are primarily utilized to enhance power system stability when integrating large PV farms. Typically employed in transmission systems, a shunt compensator is connected at the primary feeder, while a series compensator is connected at the secondary feeder. However, the literature mainly provides simulation results without extensive information on the practical operation of FACTS devices with renewable energy systems.

The proposed work introduces an adaptive filter based technique for controlling a three-phase, three-wire photovoltaic (PV) integrated Uninterruptible Alternate Power Feed (UAPF) system. The adaptive filter used is a fourth-order quadrature signal generator, as mentioned in reference [22]. Two adaptive filters are employed to estimate the fundamental positive sequence components of distorted load currents. These positive sequence components are then utilized to generate a reference signal for the shunt active filter in the PV-UAPF system. This approach reduces computational complexity and exhibits excellent dynamic response. Additionally, the series active filter of the PV-UAPF is controlled using synchronous reference frame theory to compensate for voltage sags/swells at the Point of Common Coupling (PCC).

Main advantages of the system are as follows;

- Multi-functional system providing pollution free clean energy based on solar PV power along with clean power quality.
- The power generated from PV array, supplies load power is reducing active power demand from supply system.
- This sampling of positive sequence currents obtained by adaptive filter.
- The proposed system protects sensitive loads from PCC .
- The system performance is robust under various disturbances in the load

II. PROPOSED TOPOLOGY

2.1 SYSTEM CONFIGURATION:

Fig.2.1(A) shows the configuration of a PV-UAPF system. This is a three phase system consisting of a shunt active filter and series active filter with a common DC-bus. The shunt active filter is interfaced near the nonlinear load whereas the series active is interfaced in series with the PCC. Other major components of the system include interfacing inductors, ripple filters and injection transformers. The PV array is coupled directly to the DC-bus of PV-UAPF system. A diode is used while integrating the PV array with PV-UAPF to prevent reverse power flow into PV array. The detailed design methodology of PV-UAPF is given in [2].

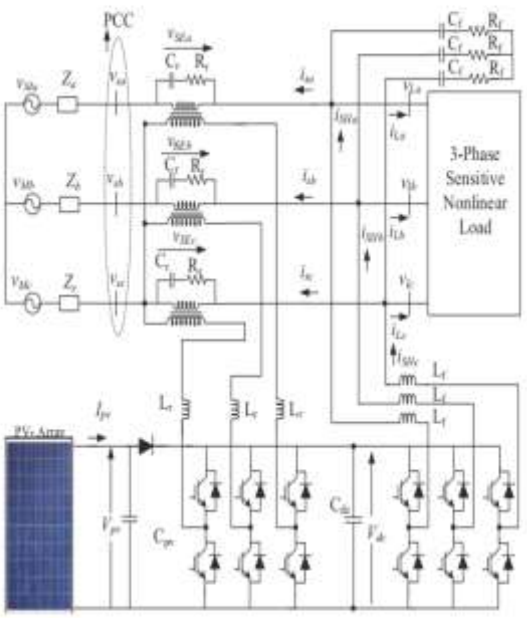


Fig.2.1.(A)System Configuration of Solar Photovoltaic Integrated Unified Active Power Filter

2.2 SYSTEM CONTROL

The major function in control of PV-UAPF system is estimation of reference signals for the shunt and series active filters. A part from this, the system also has to extract maximum power available from the PV array. The detailed description of the PV-UAPF control structure is explained as follows.

A. Control of Shunt Active Filter

The shunt active filter control is presented in Fig2.2(A) The primary task in the control of a shunt active filter is generation of reference currents. In this work, the shunt active filter is controlled using indirect current control wherein the reference for the shunt active filter is the grid current, which should only contain fundamental and active power component. The shunt active filter control blocks involve three sub-blocks i.e. DC control block, load active current evaluation block and PV feed forward block. Two adaptive filters are used to extract the fundamental positive sequence components of the load current.

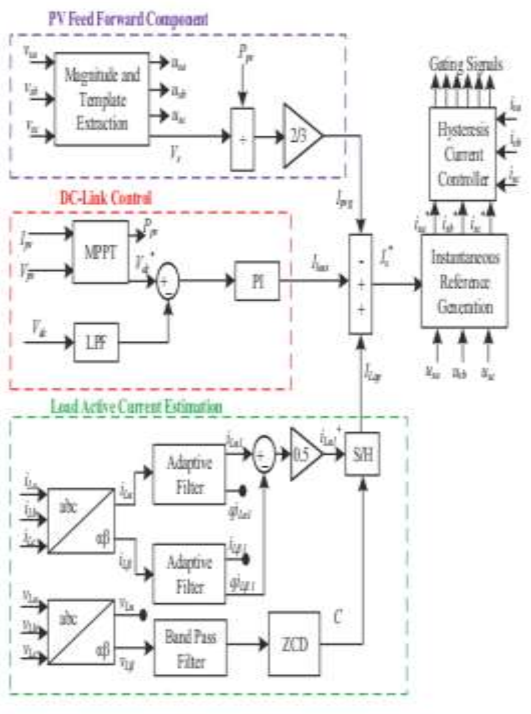


Fig. 2.2(A) Adaptive Filter Based Control of Shunt Active filter

B. Control Configuration of Series Active Filter

Fig. 2.2(B) gives the series active filter control block diagram. The PCC voltages (vsa, vsb, vsc) and load voltages (vLa, vLb, vLc) are converted to d-q domain using phase information of PCC voltages for d-q transformation. The load voltages are in-phase with PCC voltages as the series active filter injects voltages in-phase with PCC voltages. Hence the direct component of reference load voltage, is the magnitude of reference load voltage (V ∗Ld) and quadrature component of reference load voltage (V ∗Lq) is zero.

The direct component of reference series active filter voltage, is obtained as the difference between V ∗Ld and V ∗ sd. The difference between VLd and Vsd gives direct component of series active filter voltage. Similar operation is done for the quadrature components.

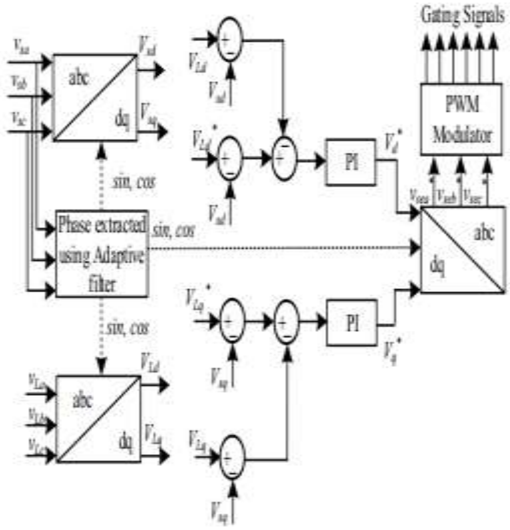


Fig.2.2(B) Control Configuration of Series Active Filter

III.SIMULATION RESULTS:

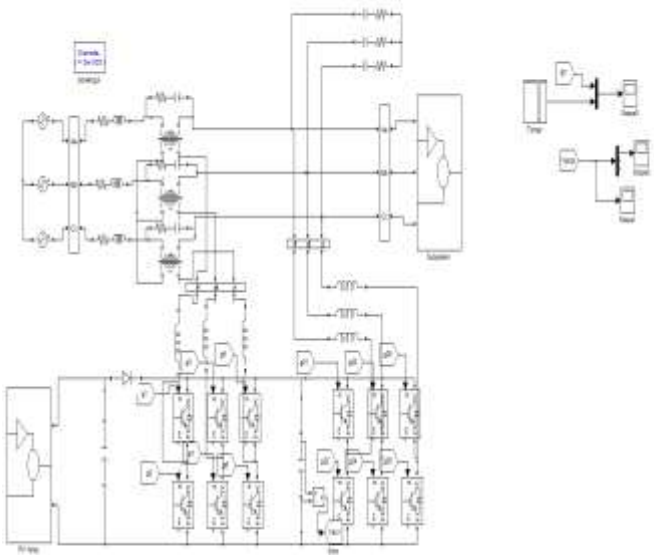


Fig:3.1 Simulation Diagram

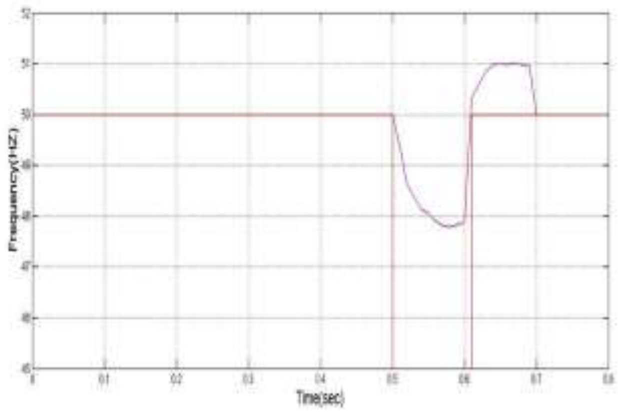
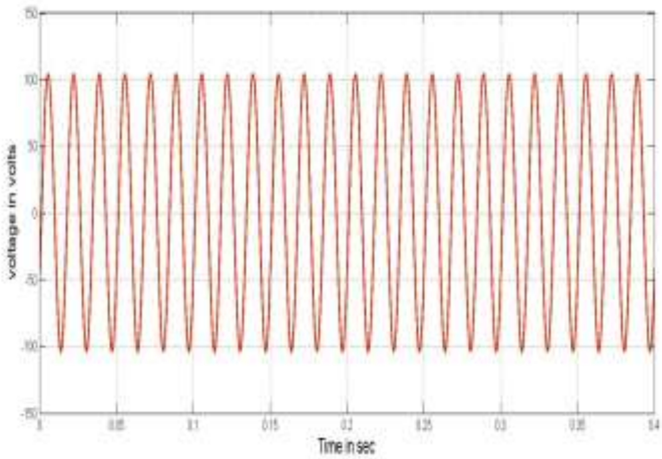
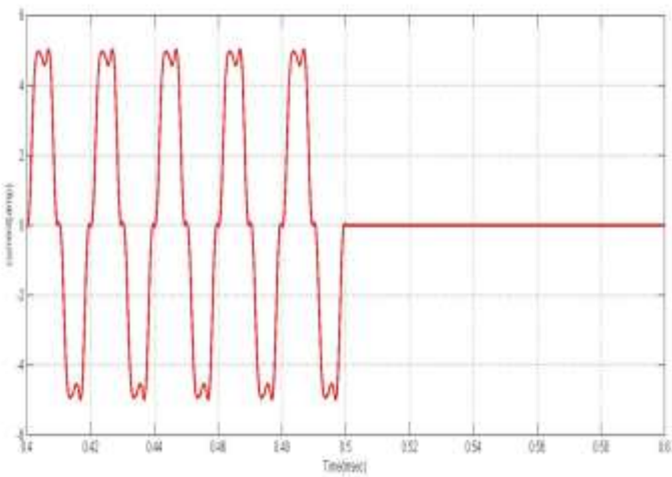


Fig. 3.2(a) Frequency Tracking Response of the Adaptive Filter



3.3b)



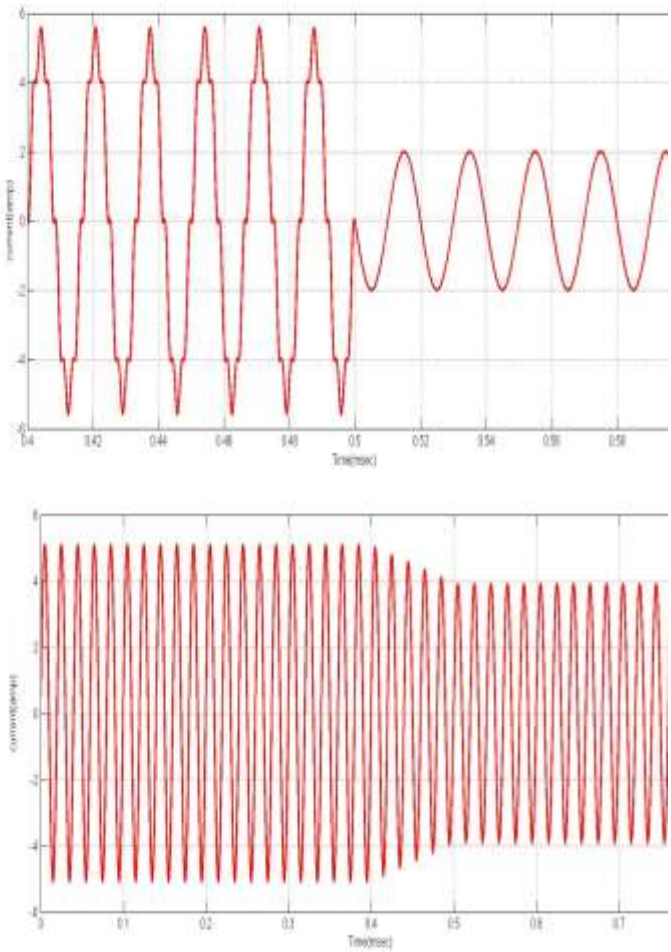


Fig. 3.4(c)Salient Signals in Extraction of Fundamental Positive Sequence Load Current using Adaptive Filter PI controller

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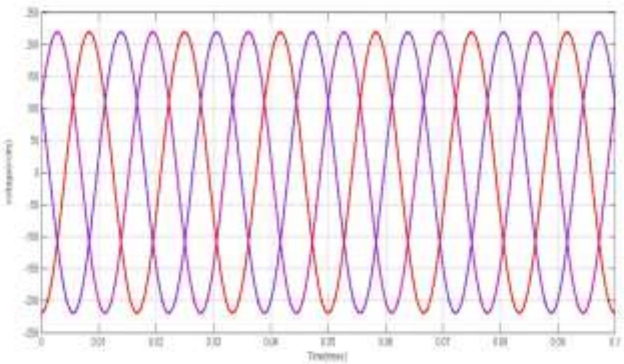

Fig3.5c)Load Voltage

IV. CONCLUSION

The performance of adaptive filter based PV-UAPF system under both steady state and dynamic conditions, have been analyzed in detail. The method of sampling the ultimate component of load current obtained through adaptive filter enables fast extraction of fundamental active element of nonlinear load currents for all phases in one sampling. Only two adaptive filters are required to extract magnitude of active component of three phase load currents. This technique requires reduced computational resources while achieving good dynamic and steady state performance in extraction of fundamental active component of nonlinear load current. The series active filter is able to regulate load voltage at 220Vunder variations of PCC voltage from 170 V to 270 V. The grid current THD is maintained at approximately 3% even though the THD of load current is 28% thus meeting requirement. The PV-UAPF system has been able to maintain the grid currents stable under unstable loading condition. This power quality issues can be received by change the topology and control algorithm according to the supplies in the distribution system. This PV-UAPF system is used to improve the power quality. The uses of fuzzy logic controller technique make the system to work effectively and make controlling process easy. It can be effectively applied in PV-UAPF systems to produce.

FUTURE SCOPE

Reducing carbon dioxide (CO_2) discharges is at the heart of the world's accelerating shift from climate-damaging fossil fuels towards clean, renewable forms of energy. The steady rise of solar photovoltaic (PV) power generation forms a vital part of this global energy transformation. In addition to fulfilling the Paris Arrangement, renewables are crucial to reduce air pollution, improve health and well-being, and provide affordable energy access worldwide. This project from the Global Renewable Energy Agency (IRENA) presents options to speed up utilization and fully unlock the biosphere's vast solar PV possible over the period until 2050.

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