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Control of Solar Photovoltaic Integrated Universal Active Filter Using Artificial Intelligence Technique

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***Abstract*- This paper organizes, a different technique based on adaptive filtering is proposed for the control of three phase worldwide active power filter with a solar photovoltaic array integrated at its DC bus. Two adaptive filters along with a zero crossing detection method are used to remove the magnitude of fundamental active component of distorted load currents, which is then used in estimation of reference signal for the shunt active filter. This technique enables extraction of active component of all three phases with reduced mathematical computation. The series active filter control is based on synchronous reference frame theory and it regulates load voltage and maintains it in-phase with voltage at point of common coupling under conditions of voltage sag and swell. In this paper An artificial intelligence technique fuzzy logic controller is used. The performance of the system is evaluated on an MATLAB/SIMULINK software under various dynamic conditions such as sag and swell in voltage at point of common coupling, load unbalancing and change in solar irradiation intensity.**

I.INTRODUCTION

There has been an increased proliferation of clean energy systems based on solar and wind energy in modern distribution system. However, due to their intermittent nature, voltage fluctuations have become a major issue in low voltage distribution system . Along with this, the advancement in semi-conductor technology has led to the widespread use of sophisticated power electronic systems like computer power supplies, switched mode power supplies, variable frequency drives, servers, etc. These systems are energy efficient but draw highly nonlinear current from the supply system. Moreover, this increasing sophistication has led to an increased sensitivity to voltage disturbances. The nonlinear currents drawn by power electronic loads, lead to increased losses in distribution transformers, distortion of voltage at the point of common coupling (PCC), etc. Thus the future systems demand clean energy along with improved power quality. The integration of clean energy generation along with active filtering, mitigates power quality problems in distribution system while also reducing dependence on fossil fuels thus leading to improved quality of environment .

Renewable energy integration with flexible AC transmission systems (FACTS) devices such as unified power flow controller (UPFC) has been discussed in. These devices are mainly used for improving stability of the power system while integrating large PV farms. Primarily, FACTS devices such as UPFC are used in transmission systems. The shunt compensator is connected at the primary feeder and series compensator is connected at the secondary feeder. Moreover, only simulation results have been provided in the literature regarding operating of FACTS devices with renewable energy systems.

However, renewable energy integration with active power filter is used in distribution systems wherein in load current compensation is a major requirement. The proposed system compensates for load current harmonics, protects sensitive loads from voltage sags/swells and also injects active power from PV array. While the structure of a active power filter is similar to FACTS devices, the shunt compensator of active filter is at load side to mitigate load current quality issues while a series active filter is at supply side. This structure has the benefit of lower rating of series active filter as current flowing to the series active filter is balanced and sinusoidal. A comparison between FACTS devices and proposed system is presented.

In this work, an adaptive filer based technique is proposed for control of three phase-three wire PV integrated UAPF system. The adaptive filter considered is a fourth order quadrature signal generator [22]. Two adaptive filters are used to estimate the fundamental positive sequence components of distorted load currents. These positive sequence components are then used to estimate reference signal for the shunt active filter of PV-UAPF system. The proposed method has reduced computational burden and has good dynamic response. The series active filter of the PV-UAPF is controlled using synchronous reference frame theory based technique to compensate for voltage sags/swells at the 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. 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].

The phasor representation of operation of PV-UAPF is given in Fig2.1(B) The signals under nominal condition have subscript'1' while signals under PCC voltage sag condition are represented with subscript '2' . The load voltage (VL1) and PCC voltage (Vs1) are equal under nominal conditions. The load current (IL1) lags behind VL1 with a phase angle φ. During sag condition, the series active filter injects a voltage (VSE) in phase with the PCC voltage (Vs2) to maintain load voltage (VL2) in same magnitude and phase as that of nominal PCC voltage (Vs1).

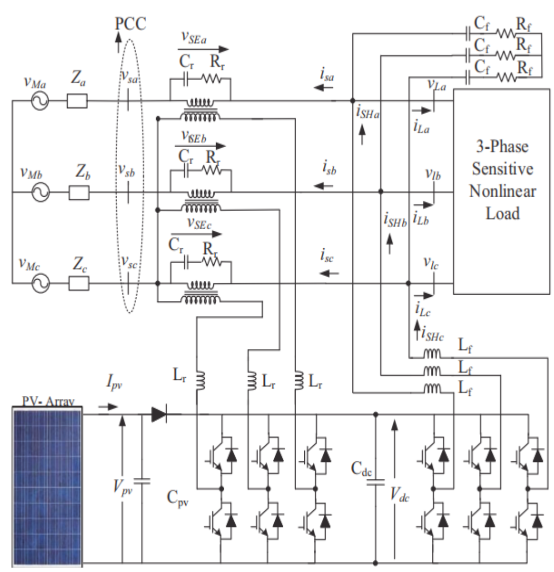


Fig.2.1.(A)System Configuration of Solar Photovoltaic Integrated Unified Active Power Filter

The shunt active filter current (ISH1, ISH2) is a combination of load reactive power and current corresponding to PV array power injection (Ipvg1, Ipvg1). The PV power generation is more than the load active power demand, and consequently the excess power is fed into the grid.

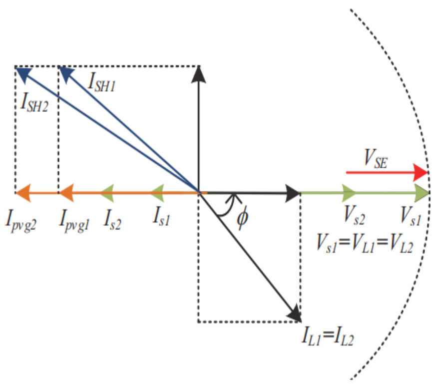


Fig 2.1(B) Phasor Representation of PV-UAPF system operating with a linear load

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(B) Theprimary 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 nus 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.

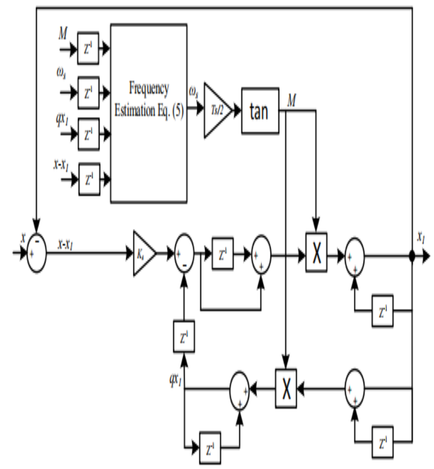


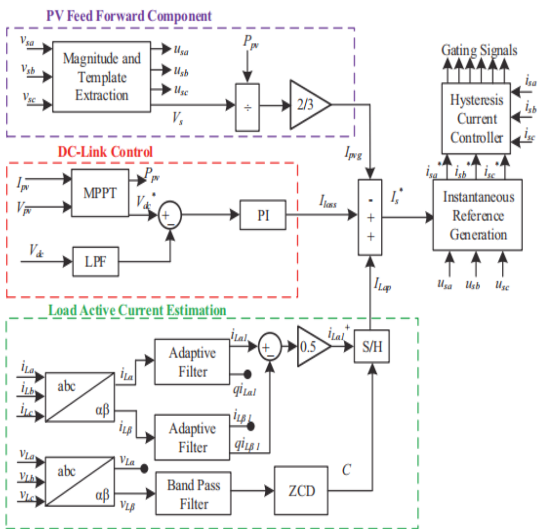
Fig 2.2(A) Configuration of Frequency Adaptive Filter

The DC-bus control block maintains the DC-link voltage of the PV-UAPF. It consists of a proportional-integral (PI) controller. The input to PI controller is error between reference voltage and sensed DC-bus voltage. The DC-bus voltage is filtered using a low pass filter to eliminate noise present in DC-bus voltage. The reference for the PI controller is obtained using a MPPT controller. The task of MPPT controller is to operate the PV array at its maximum power point.

The PV array is designed such that the maximum power point of PV array is also the operating DC-link voltage of PV-UAPF system. In this work, a perturb and observe (P&O) based MPPT controller is used due to its simplicity and ease of implementation. The perturb and observe algorithm is a hill climb search technique where, the reference voltage is updated based on difference in power between present and past sampling instants. The P&O algorithm searches for the peak of P-V curve by checking the slope on P-V curve dPpv/dVpv. The operating voltage of PV array, Vpv is perturbed with a small step change depending upon the sign of slope. Two important parameters in MPPT operation are the MPPT sampling time (Tm) and perturbation step size (δVpv). A smaller step size results in smaller oscillation around MPP point, however, it results in poor dynamic response. Similarly, a large sampling time enables the algorithm to track MPPT without getting disturbed by noise.

However, larger sampling time consequently results in poor dynamic response.

Control Configuration of Shunt Active Filter Fig. 2.2(B) Adaptive Filter Based Control of Shunt Active filterA hysteresis current controller, after comparing reference signals with the sensed signals, generates appropriate pulses for the gating circuitry of shunt active filter.



B. Control Configuration of Series Active Filter

Fig. 2.2(C) 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.

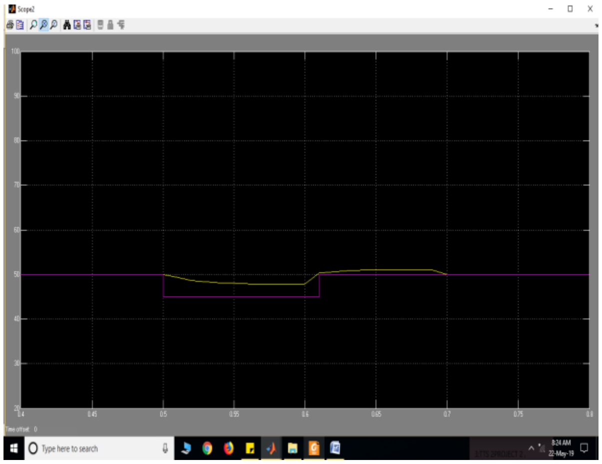
III. FUZZY LOGIC CONTROLLER:

The word Fuzzy means vagueness. When the boundary of piece of information is not clear-cut, then the fuzziness occurred. The fuzzy set theory is propounded Lotfi A. Zahed in 1965. For effective solving of the uncertainty in the problem, the fuzzyset theory exhibits immense potential. To handle the uncertainty arising due to vagueness, the Fuzzy set theory is an excellent mathematical tool. Fuzziness manifests, the understanding human speech and recognizing handwritten characters are some of the common instances. Fuzzy set theory is an extension of classical set theory.

Fuzzy set theory elements have varying degrees of membership. To describe human reasoning, the fuzzy logic utilizes the whole interval between 0 and 1. In FLC the input variables are mapped by sets of membership functions and these are known as “FUZZYSETS”.

Fuzzy set comprises from a membership function which could be defines by system parameters. The value in the range of 0 and 1 uncovers a degree of membership to the fuzzy set. “Fuzzificaton” is the process of converting the crisp input to a fuzzy value. The output of the Fuzzier module is interfaced with the guidelines. The basic operation of FLC is developed from fuzzy control rules using the values of fuzzy sets in general for the error and the difference of error and control activity. Fundamental fuzzy module is appeared in fig6.1(A). The results are consolidated to give a fresh output controlling the output variable and this procedure is known as“DEFUZZIFICATION.

1V.WAVE FORMS:



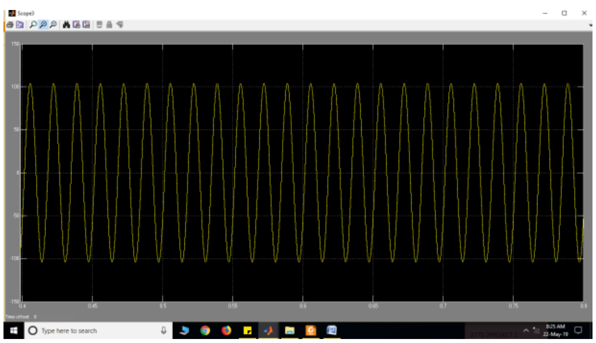
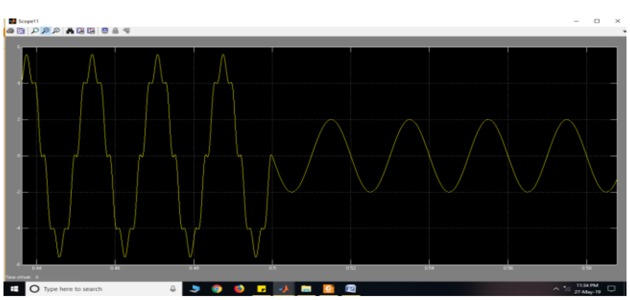
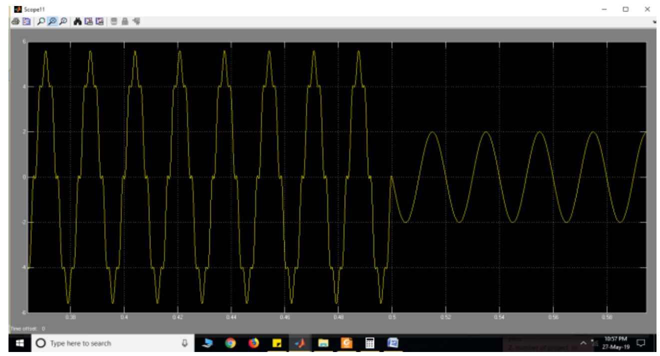


Figure 4.1 Frequency Tracking Response of the Adaptive Filter





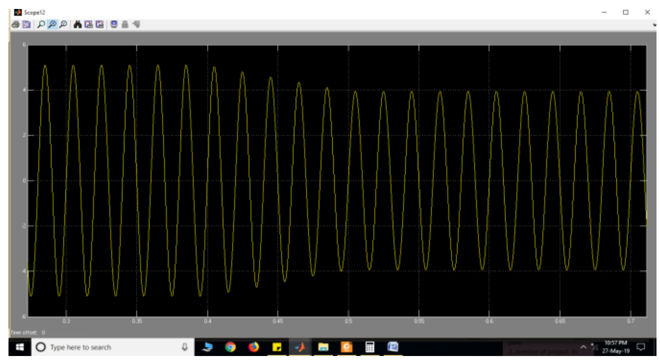
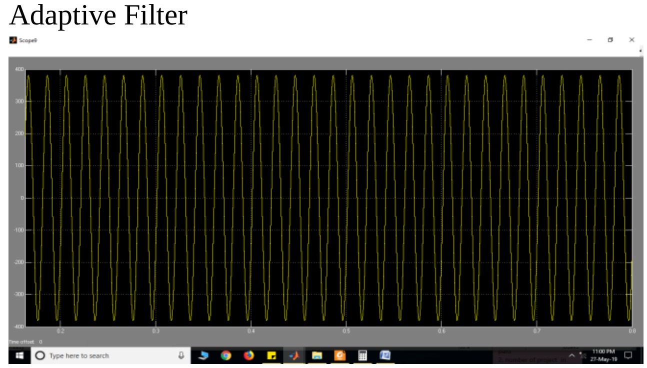
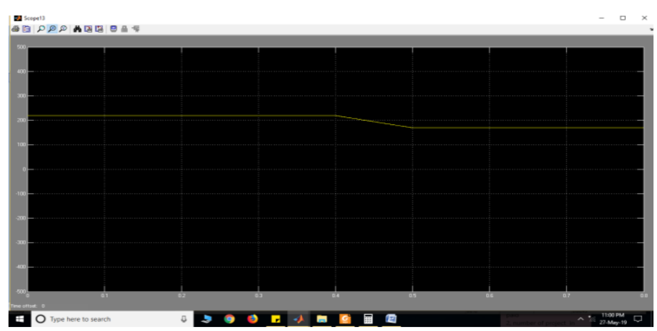


Figure 4.2 Salient Signals in Extraction of Fundamental Positive Sequence Load Current using Adaptive Filter





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.

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