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Photo Voltaic Array Integrated Three-Phase Transformer less Shunt Active Power Filter with Reduced Switch Count for Harmonic Compensation

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Abstract: *In this paper, a novel four-switch two-leg VSI topology for a three-phase SAPF is proposed for reducing the system cost and size. The proposed topology comprises a two-arm bridge structure, four switches, coupling inductors, and sets of LC PFs. The third leg of the three-phase VSI is removed by eliminating the set of power switching devices, thereby directly connecting the phase with the negative terminals of the dc-link capacitor. The proposed topology enhances the harmonic compensation capability and provides complete reactive power compensation compared with conventional APF topologies. As PVA is connected at the DC link active power is also injected into the grid consumed by the load.*

Keywords: *Harmonics, hybrid topology, nonlinear load, power quality (PQ), Transformer less inverter, Grid-connected system Photo Voltaic Array.*

1. Introduction

Voltage and current harmonics are generated in the power distribution system as a result of the proliferation of nonlinear characteristic loads. Current harmonics cause issues such as power quality, reactive power, transformer losses, voltage harmonics, as well as harmonic resonance at the distribution level. [1] Active technologies, such as shunt active power filters (SAPFs) and hybrid APFs, can help to solve these issues (HAPFs). The passive and active components of these filters are coupled in series or shunt connection. In accordance with tight harmonic regulations, these filters also restrict the current flow harmonic into the power distribution system. [2].A conventional APF consists of a three-leg bridge voltage source inverter (VSI) with a dc-link capacitor. Traditional APF topologies are inefficient because they require a matching transformer and a high number of active switching devices, such as the insulated gate bipolar transistor (IGBT). These concerns result in a system that is heavy and expensive, which is unfavorable. [3].The potential of the energy grid to offer customers with stable, optimal, and non-tolerant electricity is characterized as power quality. Power quality challenges can be divided into numerous categories. Originally, it just referred to the availability of electrical power, as well as voltage and frequency regulation within a certain range. [4] Power quality is achieving more attention as electrical devices become more sensitive, customers become more aware, and power quality pollutions in the system increase. In addition to initial requirements, power quality must consider harmonic distortion, short time transients, disrupts, interruptions, as well as flashes. [5].As part of today's grid, power electronic devices may have certain unfavorable consequences on grid parameters, power quality, and system dependability. These devices, which are widely employed in modern networks, have a direct impact on the distribution network's power quality. Inverter-based DGs, which use power electronic equipment as an interface to connect to the grid, are an example of these contaminants. [6] The crucial aspect is that the use of DG is becoming more widespread, both among individuals and among electric utilities. However, in standalone applications, the output current and voltage of DGs could be enhanced in the generation source by using some inverter switching methods. It is really important to note that multilevel inverters are among the

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most exciting inverters for using these switching methods, like harmonic elimination methods, due to various abilities. [7] Power quality issues are becoming increasingly essential as the number of DGs in today's grid grows, so paying attention to this topic is unavoidable. Several studies have been conducted on reducing the negative effects of power electronic-based DGs in microgrids that use DGs; nonetheless, this appears to be the first iterations of the multi-functional DGs concept, and much work has to be done in this regards. [8].Many devices have been proposed as PQI devices throughout the years, but each one has its own set of drawbacks, thus study on this area must continue. Even though the integration of power electronic based converters as well as nonlinear loads may degrade power quality, multifunctional DGs are among the innovative answers to the power quality dilemma. [9] The microgrid allows us to address some system issues, making the grid more dependable and safe. Microgrids were originally introduced in the 1990s, and academics began to pay greater attention to them after that. It has unique qualities that will enhance power quality; one of these features is the inclusion of many DG units of varying natures to increase overall system reliability. Because most of the DG units in use power electronics-based converters, such energy sources could be used to improve power quality. [10] Even though it performs some of the same functions as a standard converter, each power electronics-based converter deployed in microgrids has the potential to increase power quality. [11] To date, numerous studies have been conducted in the topic of improving power quality in distributed power systems, but they have largely focused on a single area and are therefore not comprehensive. [12]

2. Methodology

The proposed SAPF is implemented in different load scenarios using MATLAB/SIMULINK in this research. Essentially, there are two simulations: one with non-linear load and the other with SAPF attached. A transformer-less SAPF architecture based on a four-switch two-leg arrangement is proposed in this work. The new circuit is developed from a six-switch full-bridge inverter, unlike previous current topologies. In comparison to traditional full-bridge topologies, the novel model improves harmonic filtering and reactive power correction.

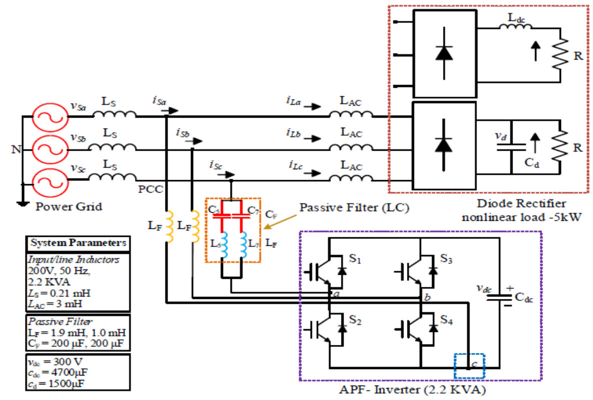

Figure 1 Proposed transformer less APF system

Proposed Four-Switch Two-Leg VSI-SAPF

A two-arm bridge construction, four switches, coupling inductors, and sets of LC PFs are all included. For a good switching scheme, the sinusoidal PWM (SPWM) modulation strategy was used in this work. To design the reference signals, the carrier signal is compared to the comparators with a single alteration.

By removing the set of power switching devices, the third leg of the three-phase VSI is eliminated, allowing the phase to be directly connected to the negative terminals of the dc-link capacitor. The removal of a single phase-leg causes a voltage imbalance or voltage variations in the dc-link. To prevent imbalance charging of the dc-link capacitors, attach the removed leg terminal to the negative terminal of the dc-bus PWM-VSI. Additionally, the ac film capacitor holds decoupling power ripples to give balanced output voltages and currents, thus stopping the flow of decoupling power ripples. The new circuit is developed from the six-switch full-bridge inverter shown in, unlike many other previous topologies. In comparison to traditional full-bridge topologies, the novel model improves harmonic filtering and reactive power correction.

3. Simulation Result & Discussion

Simulation studies are carried out in the MATLAB/Simulink environment to validate the efficiency of SAPF with the suggested controller. This section contains the electrical parameters of the SAPF that were used in simulation experiments. In simulation investigations, two scenarios for steady state and transient state circumstances are explored, and the SAPF MATLAB/Simulink Model is shown in figure.

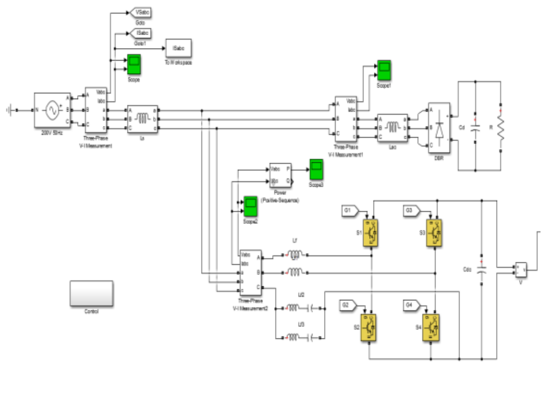

Figure 2 Proposed shunt active power filter

The above is the modeling of the proposed test system with three phase source feeding non-linear load which injects harmonics into the system. The harmonics are compensated by the SAPF connected at the PCC of the test system.

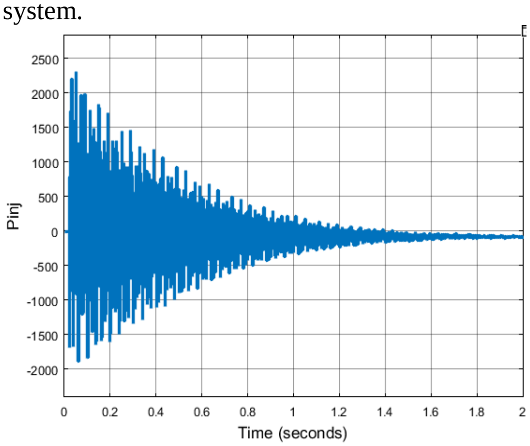

Figure 3 Injected active power of only SAPF

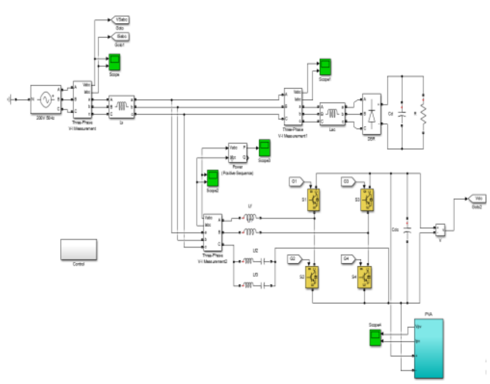

Figure 4 Proposed shunt active power filter with PVA

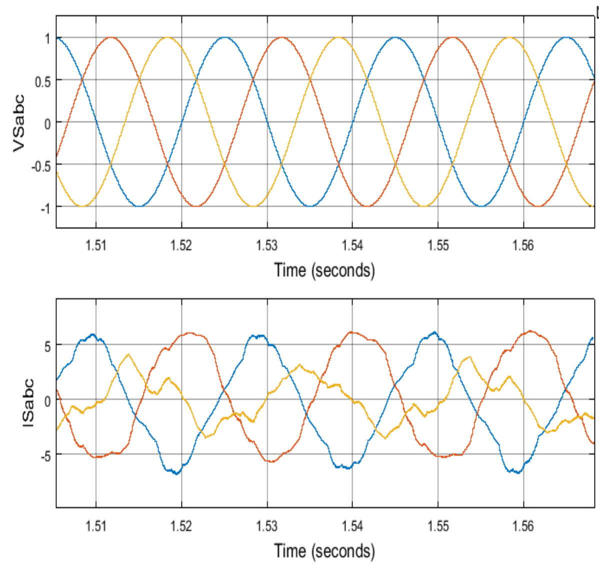

Figure 5 Source voltages and current with SAPF connected to PVA

The above graphs are the three phase source voltages and currents for the test system with PVA integrated SAPF and below are the load voltages and currents for the same.

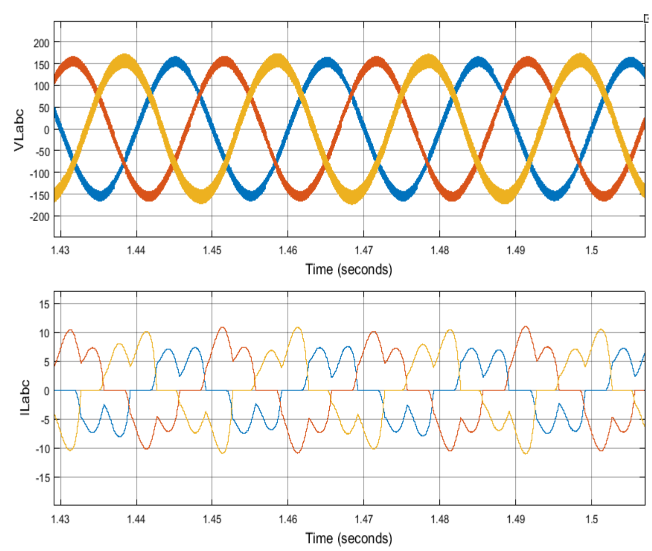

Figure 6 Load voltages and currents without SAPF connected to PVA

The below are the PVA voltage and current shared for optimal solar irradiation.

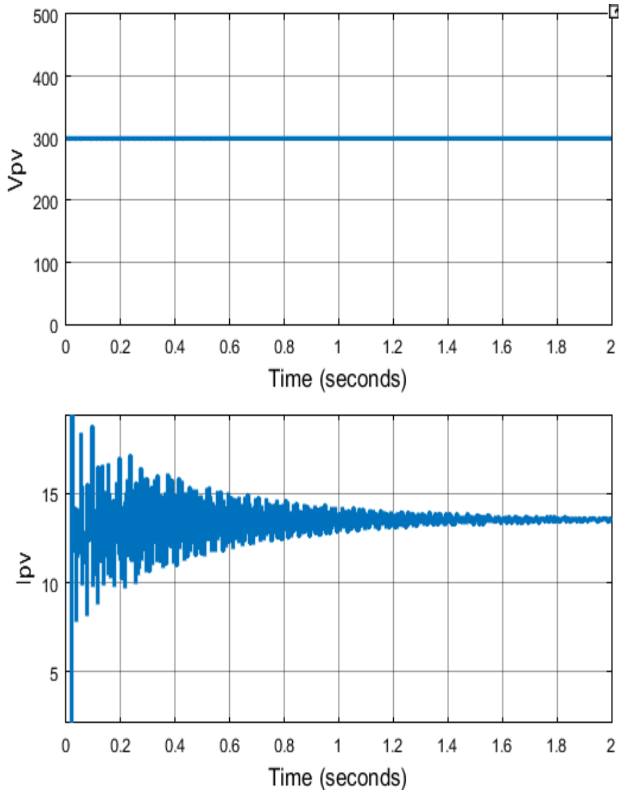

Figure 7 PVA voltage and current

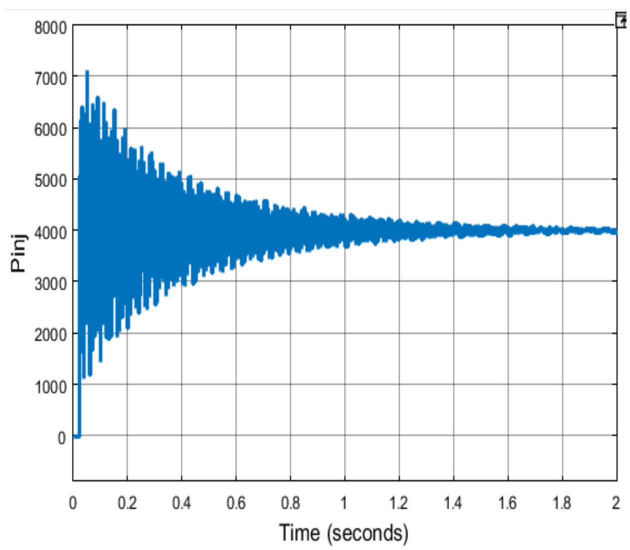

Figure 8 Injected active power of SAPF connected to PVA

The above is the total injected active power from the PVA integrated SAPF to the grid system.

4. Conclusion

The proposed APF system is more robust, efficient and stable to improve the feasibility and harmonic propagation of the power distribution system. A detail analysis of the both the active filter inverter and passive filter, including the active power capability and filtering characteristics has been presented. The control algorithm can ensure the regulated sinusoidal voltage, phase amplitude, and low THD in the power distribution system, along with dc-link voltage control. The complete simulation is carried out in Simulink environment of MATLAB software with graphs generated using powergui toolbox.

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