Multifunctional VSC Controlled Solar PV System with Active Power Sharingand Power Quality

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***Abstract*: This paper presents a multifunctional voltage sourced-converter (VSC) controlled solar photovoltaic (SPV) system with a generalized 'dq' and adaptive PLL-based approach to extractthe dual features. These include enhanced active power sharing feature based on the availability ofactive power at DC-side collector bus while also serving as an active harmonic filter (AHF). The presented control is computationally less intensive and easy to formulate compared to its conventional counterpart like synchronous reference frame theory (SRFT). The objective of this work is to effectively extract the various ancillary services offered by multifunctional VSC in the power distribution system. The primary function of any gridconnected inverter (GCI) is to serve the active power demand of the load connected at the point of interconnection (PoI) in the power distribution network. However, the multifunctional VSC with presented control approach can also be utilized as AHF to attenuate the rich harmonic content present in source current, to mitigate the load reactive current demand, and to adequately supply the zero sequences harmonic component requirement of the unbalanced and nonlinear load by the fourth leg of the multifunctional VSC. Additionally, the proposed system typically ensures the unity power factor (UPF) operation. Anincremental conductance (IC) based control technique is employed to optimize and continuously track the maximum power point (MPP) during solar intermittency. The usefulness of the proposed multifunctional VSC is demonstrated through transient test cases, conducted in the MATLAB/Simulink software environment. Additionally, its practicality is validated through a comprehensive set of experimental studies investigated on a laboratory developed prototype.**

***Keywords*: Multifunctional VSC, grid-connected SPV system, unity power factor operation, power quality improvement, renewable energysources.**

I. INTRODUCTION

In a recent year, the growing electricity demand acrossthe globe and increasing carbon emission generated by non-renewable sources have been gaining special attention from the science and engineering society. At the meantime, electric utilities are also concerned about serving the raising needs of energy. Thus, it has nowbecome mandatory to look towards renewable energy source (RES) as a promising substitute to produce green and clean power. Besides this, the development of new/and rapid switching power electronics components, and the evolution in technological advancement in semiconductor technology have played a very crucial role in converting the energy generated by RES into a useful form.

II SYSTEM ARCHITECTURE

The system envisaged in this paper is a 3P4W grid connected double-stage SPVPCS system as depicted in Fig. 1. In the present work, four-legged VSC topology is used because it has an inherent capability to offer direct control over the neutral current mitigation in a 3P4Wunbalanced system. The proposed system comprises an RES interfaced to the DC-bus of multifunctional VSC through an intermediate boost converter. The current controlled VSC is a key element of a distributed energy resources (DER) because it plays a very vital role in modulating the power before feeding it into the utility grid.Here, SPV is considered as a RES which generates power typically at variable small DC voltage. Thus, the power produced from SPV array requires a separate power conditioning stage (i.e. DC-DC or DC-AC) [8]. The DC- bus capacitor typically decouples the SPV system from theutility grid and it also allows individual control of either boost converter or multifunctional VSC. In this paper, a typical non-linear load of 20 kW is selected for the simulation studies. An SPV array is capable of providing 13.5 kW of power to the load at standard test condition (STC) [i.e. 25^{o} C & 1 kW/m^2].

III DESCRIPTION OF CONTROL SCHEME

The control algorithm of a grid-connected multifunctional VSC for a 3P4W system is depicted in Fig.2. The primary objective of multifunctional VSC withsuggested control scheme is to feed constant power to the loads connected at PoI during varying irradiance conditionwhile addressing PQ issues in the distribution system. It isimportant to mention that the duty cycle of multifunctionalVSC switches should be modulated in a periodic cycle such a way that the power consumed by the load and power injected by the VSC at PoI appears as a resistive load operating at UPF to the utility grid. Information regarding the active power exchange between SPV and utility grid is typically accumulated by regulating the DC- bus terminal voltage.

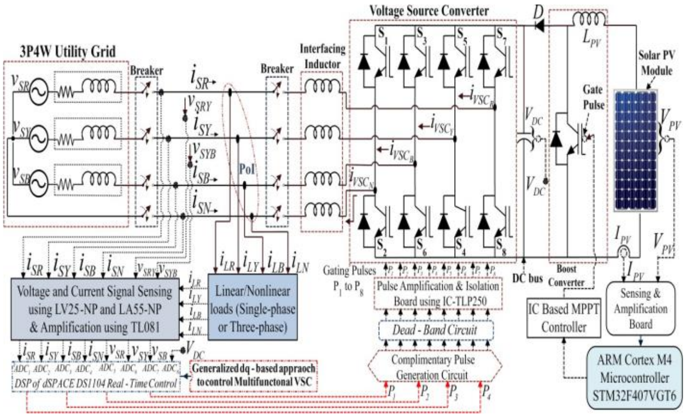

Fig. 1 System architecture for the grid-connected SPV system

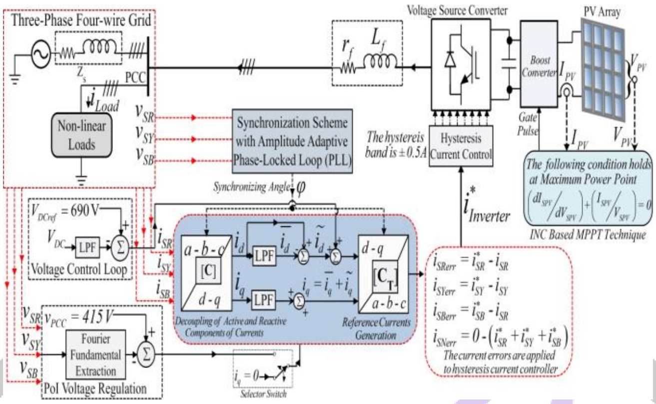

Fig. 2 Control algorithm to generate the reference currents

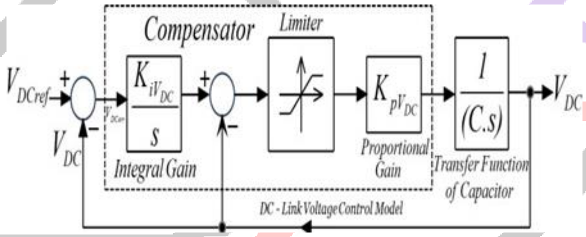

Fig. 3 Closed-loop control of the DC-bus voltage regulator

IV SIMULATION RESULTS AND DISCUSSION

An extensive transient simulation studies have been carried out to investigate the effectiveness of the presented control. It is shown that several functions can beacquired simultaneously for grid-connected DER interfaced to a 3P4W network. To demonstrate the systemperformance under different operating conditions, the notations used to represent grid voltage, grid current, load current, compensating current, DC-bus voltage, active power sharing, SPV array voltage, and SPV array current are V_{sRYB}, I_{sRYB}, I_{LR}, I_{CR}, V_{DC}, P_S Vs. P_{PV}, V_{PV}, and I_{PV}, respectively A load taken for this study demands anaverage power of 20.9 kW.

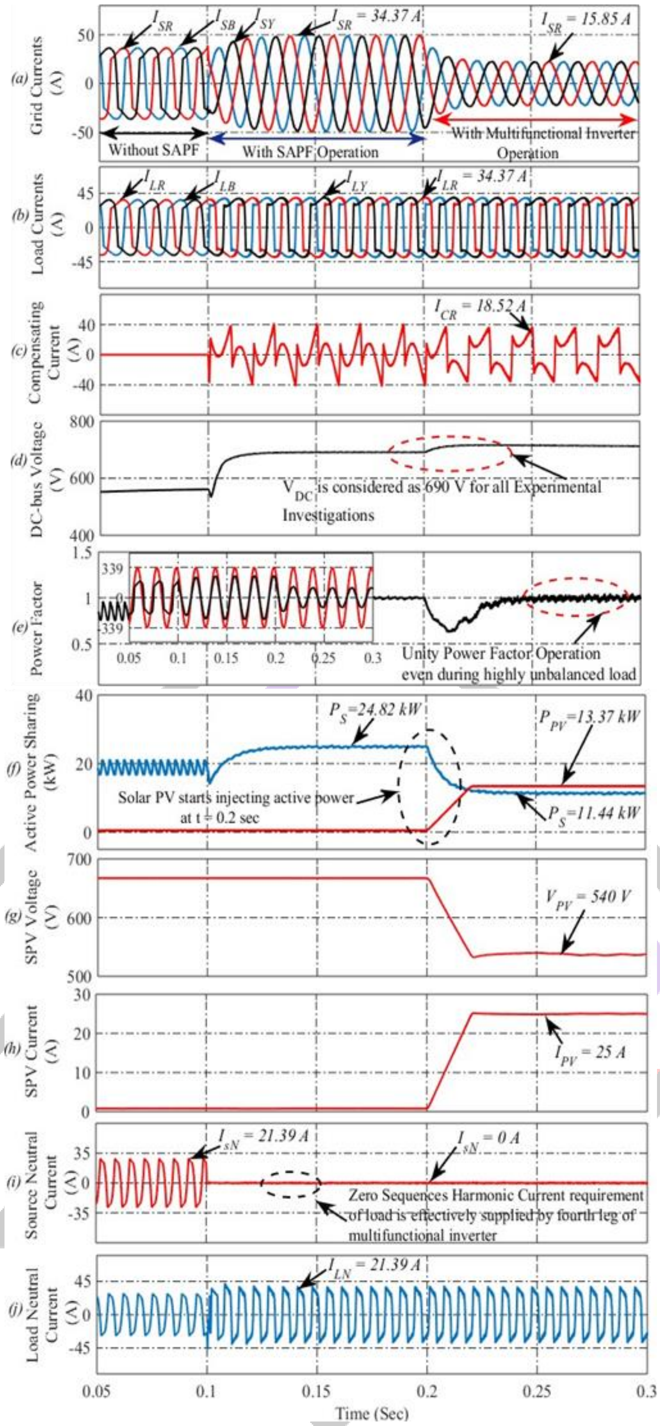

Fig. 4 System response under unbalanced loading: (a) Grid currents, (b) Load currents, (c) Compensating current, (d) DC-bus voltage, (e) Power factor, (f) Active power sharing, (g) SPV voltage, (h) SPV current, (i) Source neutral current, and (j) Load neutral current.

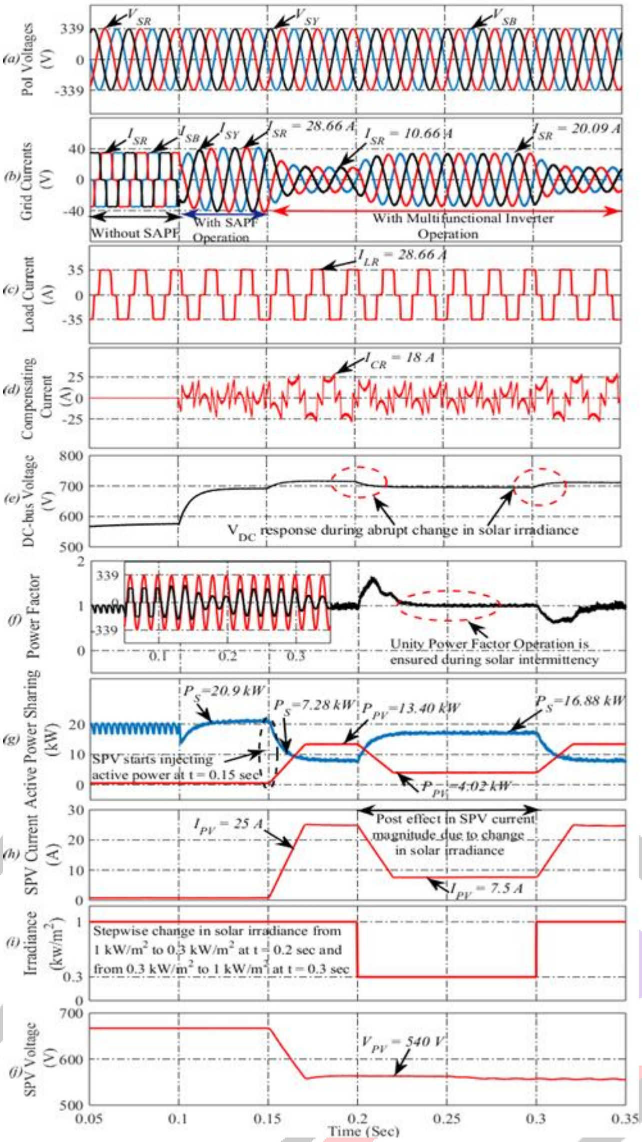

Fig. 5 System behavior under solar irradiation change: (a) PoI voltages,(b) Grid currents, (c) Load currents, (d) Compensating current, (e) DC-bus voltage, (f) Power factor, (g) Active power sharing,(h)SPV Currents (i) Solar irradiance, and (j) SPV voltage.

V CONCLUSION

A generalized „*dq*" based control approach has been presented in this paper for generating a reference current for 3P4W multifunctional VSC controlled SPVPCS. It hasbeen experimentally demonstrated that the proposedsystem not only injects the active power into the electric grid but also provides a various PQ solutions in the electric distribution network. The aforementioned multifunctional VSC can be employed to fulfill the following approaches:

1) to suppress the source current harmonics generated bythe nonlinear load,
2) to provide the load neutral current demand by thefourth leg of the VSC.
1. to share the active power requirement of load based onthe availability of active power at DC-bus terminal

It is evident from the results presented in this paper that this approach actively eliminates the need forsupplementary power filtering equipment to enhance the PQ at PoI. The practicality of the proposed approach is verified through both substantial MATLAB/Simulink simulation studies and detailed experimental investigation. Furthermore, the system performance is found to be adequate. It is also demonstrated that thetraditional GCI can be effectively utilized as a multi- functional VSC with suitable control technique.

It is further noted that the PQ enhancement and active power transfer into the utility grid have been demonstrated extensively under various operating conditions to confirm the performance and control of multifunctional VSC based grid-connected SPVPCS. Besides this, it is shown that the grid currents are maintained to be balanced and sinusoidal at UPF despite varying insolation, current unbalancing, and harmonics. Moreover, the fourth leg of the VSC is adequately employed to mitigate load neutral current locally so thatits flow in grid side can be blocked.

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