An Improved Grid Tied SPV System With Adaptive DC Link Voltage for CPI Voltage Variations

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Abstract: This paper deliberates about the design and control of a grid interfaced solar photovoltaic (SPV) system which also mitigates power quality problems in three-phase distribution system. The grid connected SPV system consists of a PV array, DC/DC converter, a three leg VSC (Voltage Source Converter), grid and linear/nonlinear loads. Along with this, a suitable control algorithm (based on Instantaneous Reactive Power Theory) is also implemented for improved power quality so as to provide zero voltage regulation (ZVR) or power factor correction (PFC) along with harmonic elimination and load balancing. Simulation results obtained using MATLAB/Simulink shows the performance of the proposed control strategy for power quality improvement under various modes of operation.

Keywords: Instantaneous Reactive Power Theory (IRPT), Solar Photo Voltaic (SPV), Zero Voltage Regulation (ZVR), Power Factor Correction (PFC)

I. INTRODUCTION

Photovoltaic (PV) energy has grown at an average annual rate of 60% in the last five years; surpassing one third of the cumulative wind energy installed capacity and is quickly becoming an important part of the energy in some regions and power systems. This has also triggered the evolution of classic PV power converters from conventional single phase grid-tied inverters to more complex topologies to increase efficiency, power extraction from the modules and reliability without impacting the cost. Single stage grid interfaced, two stage grid interfaced and multi level grid interfaced are the main potential configurations for SPV power generating system. By the effective control of SPV generating system, PQ problems of AC distribution system caused by nonlinear and unbalanced loads can be mitigated. Depending upon the needs and applications, grid-connected PV generation systems can be found in different sizes and power levels and are subdivided depending on their power rating: small scale from a few watts to a few tens of kilowatts, medium scale from a few tens of kilowatts to a few hundreds, and large scale from a few hundreds of kilowatts to several hundreds of megawatts. In addition, PV systems can be further classified depending on the PV module arrangement: a single module, a string of modules, and multiple strings and arrays (parallel connected strings) [1]. The two stage SPV power generating system has not considered the PQ problems in detail [2-4]. The grid interfaced SPV generating systems have used various control algorithms which have focused on PQ problems limited to itself and on the PQ improvement on converter side only. But, the PQ problems are dominant in the grid because of various non-linear loads in distributed system, and the PQ issues include poor power factor, voltage regulation and reactive power compensation at AC mains. In distributed power generation, voltage source converter (VSC) is used as a power quality conditioner for effective utilization after suppression of power quality problems. The dynamic performance of power quality conditioner depends upon the design of power circuit elements as well as control algorithm. It has been found that transferring reactive power to long distances from the grid to satisfy the load requirements is very ineffectual task. Hence, SPV generating systems should be situated near the load for reactive compensation of the load. Different conventional control schemes like SRFT (Synchronous Reference Frame Theory), IRPT(Instantaneous Reactive Power Theory)[5], ILST (Improved Linear Sinusoidal Tracer), neural network, enhanced phase locked loop (EPLL), novel adaptive DC link voltage control algorithm etc [6] are presented for the integration of SPV system with three-phase grid. Thus, there is a need for continuous development of control algorithms for the optimal switching of VSC to get a fast, flexible and reliable grid integrated SPV system.

II. BACKGROUND WORKS

Demand for clean, economical, and renewable energy has increased consistently over the past few decades. Among a variety of renewable energy resources available, solar energy appears to be a major contender due to its abundance and pollution-free conversion to electricity through photovoltaic (PV) process. Increasing interest in PV systems, demands growth in research and development activities in various aspects such as Maximum Power Point Tracking (MPPT), PV arrays, anti-islanding protection, stability and reliability, power quality and power electronic interface. With increase in penetration level of PV systems in the existing power systems, these issues are expected to become more critical in time since they can have noticeable impact on the overall system performance. More efficient and cost-effective PV modules are being developed and manufactured, in response to the concerns raised by the PV system developers, utilities and customers. Numerous standards have been designed to address power quality and grid-integration issues. Extensive research in the field of MPPT has resulted in fast and optimized method to track the maximum power point. Regarding power electronic converter to interface PV arrays to the grid, Voltage Source Inverter (VSI) is a widely used topology to date.

The tripping of the plant causes generation loss just in case of grid-tied PV generation system. In general, grid tied VSCs have underneath voltage and overvoltage protection. The nominal vary of point for underneath voltage and over voltage is around zero.9 pu and 1.1pu. This variety is incredibly slim as a result of reasons like converter could lose management, increase in converter rating, and converter losses at low voltage etc. just in case of the weak distribution system, a large voltage variation is ascertained. Throughout peak loading condition, a sustained voltage dip or underneath voltage is ascertained normally. The sensible vary of voltage variation is regarding ±15% of the nominal voltage. Normally in such wide variation of distribution system the shunt connected convertor visits oftentimes. However, just in case of tripping of convertor the PV generation is lost even once PV power is obtainable. Therefore, minimizing convertor visits indirectly will increase energy yield from the put in plant. The planned system is capable of operating with big selection of voltage variation thence avoids the generation loss. The employment of 2 stage SPV generation system has been planned by many researchers. Conventionally a DC-DC convertor is employed as 1st stage that serves the aim of MPPT. The duty magnitude relation of DCDC convertor is therefore adjusted that PV array operates at MPP purpose. The second stage may be a grid tied VSC (Voltage supply Converter) that feeds the facility into the distribution system. one section 2 stage grid tied PV generation system with constant DC link voltage. Moreover, the 3 section grid tied PV generation system with constant DC link voltage management is additionally. The idea of loss reduction by adaptative DC link voltage for VSC in hybrid filters whereby, the DC link voltage is adjusted consistent with reactive power demand of filter. However, within the planned system the DC link voltage of VSC is formed adaptative with relevancy CPI voltage variation. Moreover, the circuit topologies in each the systems square measure totally different. For correct management of VSC currents, the DC link voltage reference is about quite peak of 3 section line voltages. The limitation for current management in single-phase grid connected convertor is shown. Considering the variation of CPI (Common purpose of Interconnection) voltage, the reference DC link voltage is unbroken on top of the most allowable CPI voltage. Thus just in case of fastened DC link voltage management for VSC, the system continuously operates at a DC link voltage love worst case condition.

III. SYSTEM CONFIGURATION

'The system configuration for the proposed system is shown in Fig. 1. A two stage system is proposed for grid tied SPV system. The first stage is a DC-DC boost converter serving for MPPT and the second stage is a two-level three phase VSC. The PV array is connected at the input of the boost converter and its input voltage is controlled such that PV array delivers the maximum power at its output terminals. The output of boost converter is connected to DC link of VSC. The DC link voltage of VSC is dynamically adjusted by grid tied VSC on the basis of CPI voltage. The three phase VSC consists of three IGBT legs. The output terminals of VSC are connected to interfacing inductors and the other end of interfacing inductors are connected to CPI. A ripple filter is also connected at CPI to absorb high frequency switching ripples generated by the VSC.

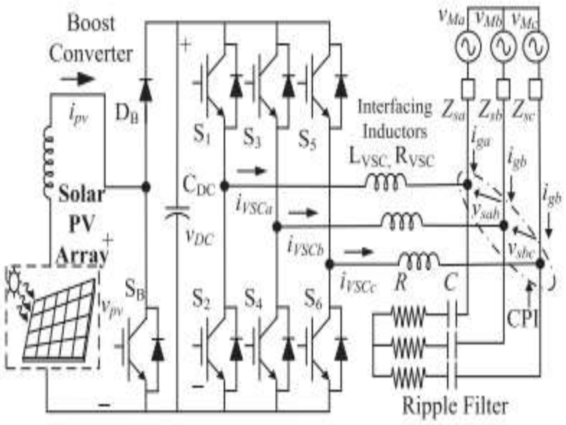


Fig. 1. System configuration.

The basic control approach for the SPV system is shown in Fig. 2. The control of the system can be divided into two main parts, which are control of the boost converter and control of a grid tied VSC. The input voltage of a boost converter is adjusted according to MPPT algorithm and the output voltage of boost converter, which is also the DC link voltage of VSC is also kept adaptive according to CPI voltage condition. In overall, the proposed system is operated such that both the input and output voltages of boost converter are adjusted according to sensed variables of the circuit. The boost converter feeds the power to the DC link of VSC, which then feeds that power into the three-phase grid at unity power factor with respect to CPI. A composite InC based MPPT technique is used to estimate the reference PV array voltage and a PLL-less control is proposed for the control of the VSC. The amplitude of the refrence grid currents is estimated using a PV feedforward (PVFF) term and a PI controller DC link voltage error. A set of unit vectors is estimated from grid voltages to synchronize output currents of VSC. The estimated reference grid currents are compared with sensed grid currents and a hysteresis current controller is used to generate switching logic for VSC.

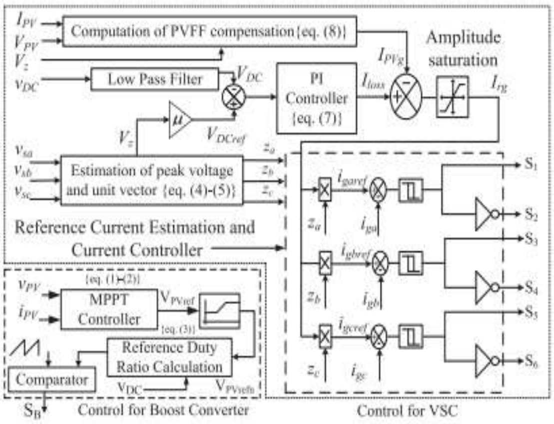
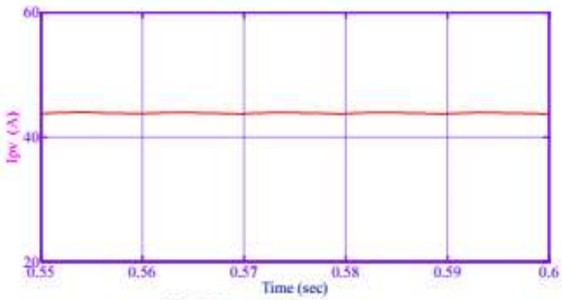


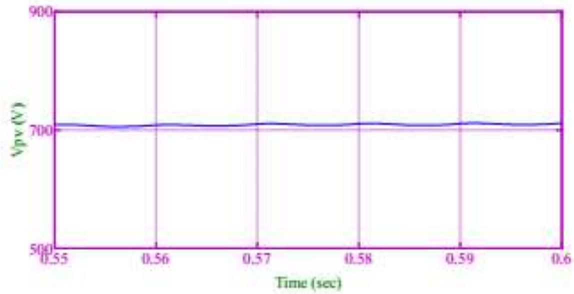
Fig. 2. Block diagram for control approach.

IV. SIMULATION RESULTS

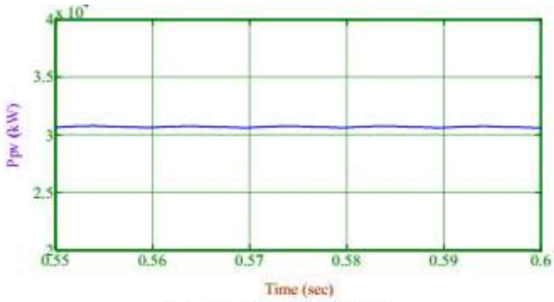
In this section, simulations are given to demonstrate the validity and advantage of the proposed method. The proposed single-stage three phase SPV power generating system integrated with the grid is modeled and simulated in MATLAB/Simulink.



(a) PV output current



(b) PV Voltage



(c) Maximum Power

V. CONCLUSION

In this paper, the control algorithm has been based on comparison with the four-leg converter shows that the number of switches is reduced in the proposed configuration, thus reducing the complexity and cost of the system. Thus the control approach based on the instantaneous reactive power theory has compensated the reactive power and the dc bus voltage is almost maintained to the reference value under all disturbances. Hence the proposed grid interfaced SPV power generating system is capable to inject active power into the grid and able to compensate for load reactive power and load current harmonics

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