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A Three-Phase Grid Tied Spv System with Adaptive Dc Link Voltage Gor Cpi Voltage Variations

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Abstract: *This proposed model manages a three-phase two stage grid tied SPV (solar photo voltaic) framework. The main stage is the boost converter, which fills the need of MPPT (maximum power point tracking) and sustaining the removed sunlight based validity to the DC connection of the PV inverter, while the second stage is a two-level VSC (voltage source converter) serving as PV inverter which bolsters control from a support converter into the matrix. The model likewise utilizes a adaptive DC link voltage which is made adaptive by modifying reference DC interface voltage as per CPI (common point on intersection) voltage. This adaptive DC link voltage control helps in the reduction of switching power losses. A sustained forward term for solar contribution is utilized to improve the dynamic response and the system is tested considering realistic grid voltage variations for under voltage and over voltage. The performance improvement is verified experimentally. The proposed system is advantageous for not only frequent and sustained under voltage (as in the cases of far radial ends of Indian grid) but also for normal voltages at CPI. The THD (total harmonics distortion) of grid current has been found well under the limit of an IEEE-519 standard.*

Index Terms—Adaptive DC link, MPPT, overvoltage, solar PV, two-stage, three phase, under voltage.

INTRODUCTION:

The electrical energy has a vital role in development of human race in the last century. The diminishing conventional primary sources for electricity production have posed an energy scarcity condition in front of the world. The renewable energy sources such as solar, wind, tidal etc are few of such options which solve the problem of energy scarcity. The cost effectiveness of any technology is prime factor for its commercial success. The SPV (Solar Photovoltaic) systems have been proposed long back but the costs of solar panels have hindered the technology for long time, however the SPV systems are reaching grid parity.

The solar energy based systems can be classified into standalone and grid interfaced systems. The energy storage (conventionally batteries) management is the key component of standalone system. Various problems related to battery energy storage standalone solar energy conversion systems are discussed.

Considering the problems associated with energy storage systems, the grid interfaced systems are more preferable, in case the grid is present. The grid acts as an energy buffer, and all the generated power can be fed into the grid. Several grid interfaced SPV systems are proposed in past addressing various issues related to islanding, intermittency, modeling etc.

With growing power system, the attention is moving from centralized generation and radial distribution to distributed generation. The distributed generation can bring in several advantages such as reduction in losses, better utilization of distribution resources, load profile flattering etc. The SPV systems provide a good choice for distributed generation system considering small scale generation from rooftop solar, modularity of power converter and static energy conversion process. The initial investment in SPV systems is high because of high cost of solar panels. Therefore, considering the initial investments for any installed plant, the aim is to extract maximum energy output from the given capacity. To accomplish the objective of extraction of maximum energy from an installed PV array several techniques are proposed in the literature.

Maximum power point tracking:

Maximum power point tracking (MPPT or sometimes just PPT) is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions.

Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermo photovoltaics.

PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

Voltage source converter:

Voltage source converters operating with the specified vector control strategy can perform independent control of active/reactive power at both ends. This ability of VSC makes it suitable for connection to weak AC networks, i.e. without local voltage sources. For power reversal, the DC voltage polarity remains the same for VSC based transmission system and the power transfer depends only on the direction of the DC current.

Solar photovoltaic system:

A photovoltaic system, also PV system or solar power system is a power system designed to supply usable solar power by means of photo voltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling, and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline. Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system (BOS). Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while off-grid or stand-alone systems only account for a small portion of the market.

Fig: photovoltaic cell

Under voltage:

Under voltage is defined as a sudden drop in the root mean square (r.m.s.) voltage and is usually characterized by the remaining (retained) voltage. Under voltage is thus, short duration reduction in r.m.s. voltage, caused mainly by short circuits, starting of large motors and equipment failures. Furthermore, under voltage may be classified by their duration as shown in

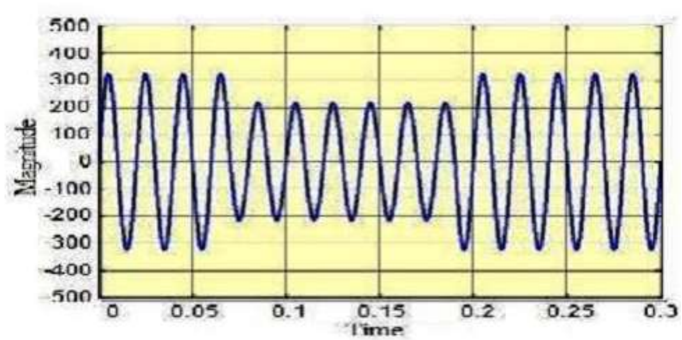
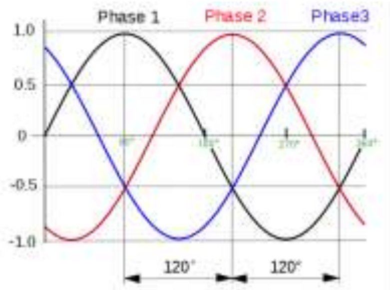


Fig: under voltage

Three-phase:

In electrical engineering, three-phase electric power systems have at least three conductors carrying alternating current voltages that are offset in time by one-third of the period. A three-phase system may be arranged in delta (Δ) or star

(Y) (also denoted as wye in some areas). A wyes system allows the use of two different voltages from all three phases, such as a 230/400 V system which provides 230 V between the neutral (centre hub) and any one of the phases, and 400 V across any two phases. A delta system arrangement only provides one voltage magnitude, however it has a greater redundancy as it may continue to operate normally with one of the three supply windings offline, albeit at 57.7% of total capacity. Harmonic current in the neutral may become very large if non-linear loads are connected.



Total harmonic distortion (THD):

The total harmonic distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Distortion factor, a closely related term, is sometimes used as a synonym.

In audio systems, lower distortion means the components in a loudspeaker, amplifier or microphone or other equipment produce a more accurate reproduction of an audio recording.

In radio communications, lower THD means pure signal emission without causing interferences to other electronic devices. Moreover, the problems of distorted and not eco-friendly radio emissions appear to be also very important in the context of spectrum sharing and spectrum sensing.

SYSTEM CONFIGURATION:

The system configuration for the proposed system is shown in below figure. 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. The values of various components and parameters used in simulation and experimentation are given in Appendix A.

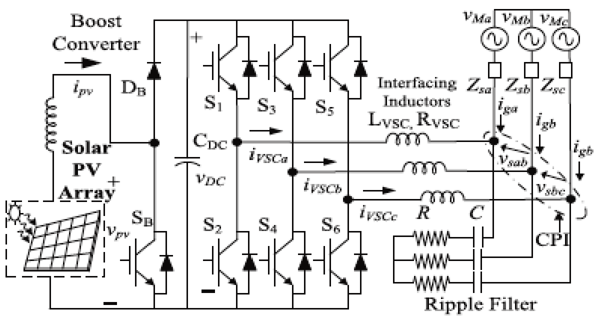


Fig: System configuration.

CONTROL APPROACH:

The basic control approach for the SPV system is shown in the below figure. The control of the system can be divided into two main parts: 1) control of the boost converter and 2) control of a grid tied VSC. The input voltage of a boost converter is adjusted according to MPPT algorithm and the output 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 reference grid currents is estimated using a PV feed forward (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. The detailed formulation for control algorithm is presented in the latter half of this section.

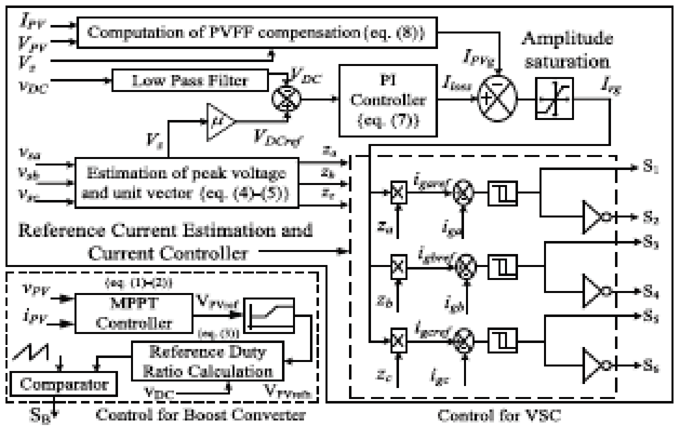
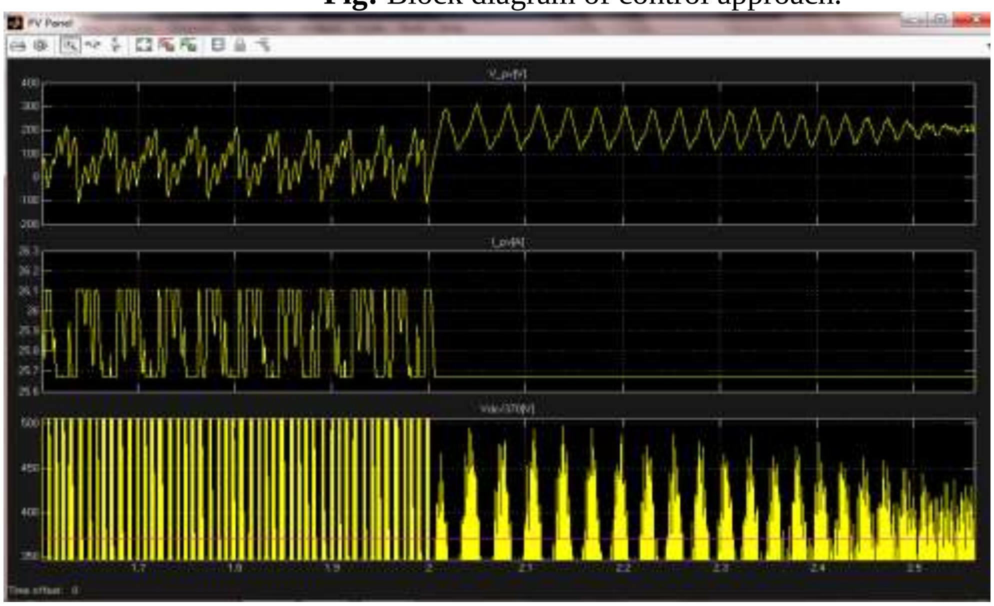


Fig: Block diagram of control approach.



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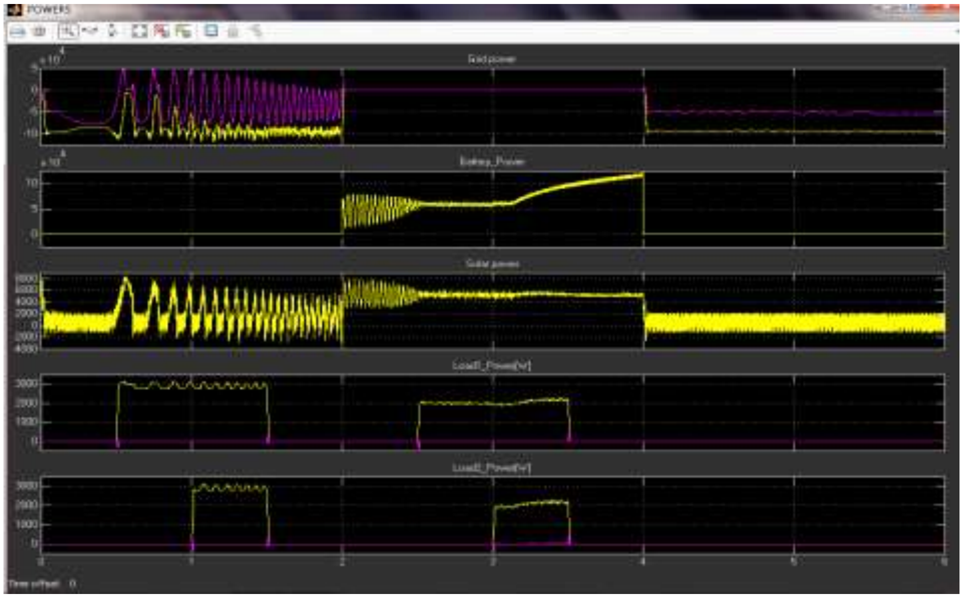
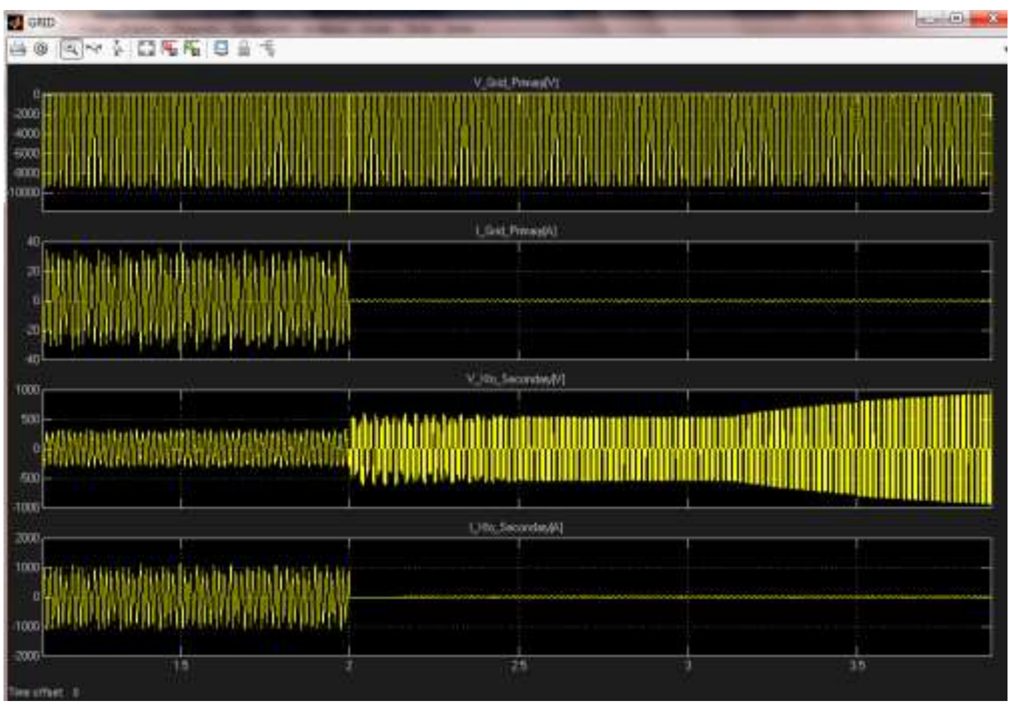
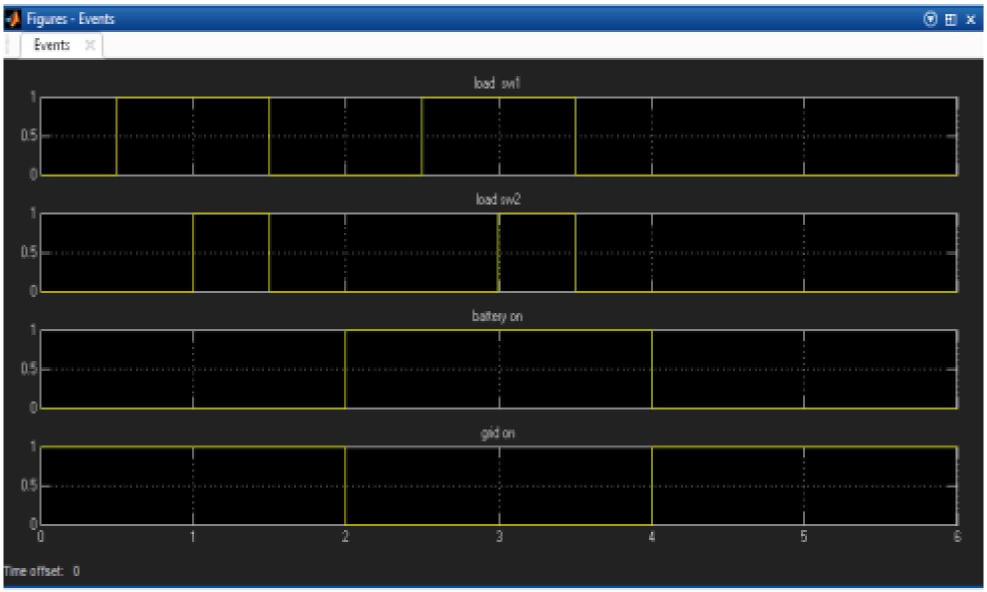
Simulation Results:







Conclusion:

A two-stage system has been proposed for three-phase grid connected solar PV generation. A composite InC based MPPT algorithm is used for control of the boost converter. The performance of proposed system has been demonstrated for wide range of CPI voltage variation. A simple and novel adaptive DC link voltage control approach has been proposed for control of grid tied VSC. The DC link voltage is made adaptive with respect to CPI voltage which helps in reduction of losses in the system. Moreover, a PV array feed forward term is used which helps in fast dynamic response. An approximate linear model of DC link voltage control loop has been developed and analyzed considering feed forward compensation. The PV array feed forward term is so selected that it is to accommodate for change in PV power as well as for CPI voltage variation. A full voltage and considerable power level prototype has verified the proposed concept. The concept of adaptive DC link voltage has been proposed for grid tied VSC for PV application however, the same concept can be extended for all shunt connected grid interfaced devices such as, STATCOM, D-STATCOM etc. The proposed system yields increased energy output using the same hardware resources just by virtue of difference in DC link voltage control structure. The THDs of the grid currents and voltages are found less than 5% (within IEEE-519 standard). The simulation and experimental results have confirmed the feasibility of proposed control algorithm.

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