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IJIEMR Transactions, online available on 30th Dec 2018. Link :

http://www.ijiemr.org/main/index.php?vol=Volume-07&issue=ISSUE-13

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Volume 07, Issue 13, Pages: 682–687.

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LOAD COMPENSATING SOLAR PV GENERATION SYSTEM WITH A PLL-LESS SCHEME USING SINGLE-PHASE GRID INTERFACED

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Abstract— single-phase grid-connected photovoltaic generation systems under variation of irradiance is presented in this research. For synchronizing to grid voltage is used a synchronization algorithm by using two phase locked loop (PLL) as a reference and feedback for the synchronization controller. Simulation and experiment results show that the Grid-Connected controller functions well in regulating the output voltage and current under variation of irradiance. The use of renewable energy Sources are increasing day by day. These sources are clean, pollution free, and inexhaustible. The single stage topology utilized in the grid connected PV system has the advantages of high efficiency and low cost compared with the two stage topology the primary function of the grid connected inverter in a single stage SPV system is to supply active power into load and grid. The added functions to the grid connected inverter are compensation for reactive power requirements and mitigation of the harmonics produced by the nonlinear loads connected at the point of grid connection. This project proposes a single-phase double-stage scheme for grid interfaced load compensating solar photovoltaic (PV) generating system. The scheme serves twofold objectives of alleviating power quality issues such as power factor correction and harmonics mitigation, while simultaneously extracting the maximum power generated by the PV unit. A simple notch filtering control algorithm is designed to facilitate extraction of the real component of load current, exempting the services of a phase locked loop (PLL). The absence of a PLL reduces the system dependence on the proportional-integral (PI) controller tuning, which in turn improves the dynamic response and makes the system quite robust. The proposed solar PV generation system retains its ability of mitigating harmonics on cloudy days and also provides opportunity for night time utilization of available resources. The system has been analyzed under both linear and nonlinear varying loads using simulation results.

Index Terms—Grid connection, phase locked loop (PLL), proportional-integral (PI).

INTRODUCTION

A variety of systems has been developed for the integration of solar PV with different types of distribution networks. A three-phase double-stage synchronous reference frame theory (SRFT)-based control for grid integrated solar PV generating system has been introduced by Verma et al.. The control algorithm facilitates power factor correction and zero voltage regulation, along with maximum power extraction from the solar PV array. The dependence on PLL for reference current extraction makes the control dependent on proportional-integral (PI) controller tuning, which reduces the robustness of the system and deteriorates the dynamic response. A three-phase single-stage one cycle control (OCC)-based system has been discussed in The design

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utilizes a current sourse inverter (CSI)-based topology and the control can be implemented digitally without the services of a digital signal processor, as opposed to the improved linear sinusoidal tracer (ILST)-based control discussed in [14]. A further simplified and more stable, modified OCC for both single-phase and three-phase bidirectional converters has been discussed in [15]. The recent encouragements to residential solar PV generation have seen a development of control schemes for low power single-phase solar PV generating systems. In, the authors have presented a six switch inverter topology using the inverse Park's transform-based PLL for connecting solar PV system to the grid. Due to its cost effectiveness and simplicity of implementation, the OCC-based system has been utilized for single-phase applications too in .An OCC-based system for grid integration of single-phase solar PV generation has been introduced. The amount of power extracted by this single stage system is highly dependent on the values of its operating parameters, which requires regular tuning in order to maximize the output power for different irradiance levels [19]. It proposes a multi objective optimization procedure that combines the OCC technique in [18] with the P&O MPPT algorithm, in order to make the system operate at the MPP for different irradiance levels. A dual inverter-based multilevel topology for grid tied PV system has been shown in [20].The exponential increase in domestic nonlinear loads such as use of power electronic equipments in air conditioners, electronic fan regulator, LED and fluorescent lighting, and TV sets has exacerbated the problem of harmonics in the distribution system. These nonsinusoidal currents do not contribute to any active power transfer but they increase the rms current in the distribution transformer and well as distribution feeder, which in turn increases losses in the distribution system. Moreover, the harmonics currents also distort the voltage at the point of common coupling (PCC). Adaptive notch filters are proposed by researchers for estimation of frequency and selected frequency component from a distorted signal [21]. A nonlinear differential equation is used to update the frequency in adaptive notch filters. The allowable range for grid frequency variation is 49.2–50.3Hz. Considering the fact that the grid frequency is almost constant, the calculation burden for phase locked loop (PLL) and estimation of grid frequency is avoided and a simple notch filter is used in the proposed work and simulation results are shown to prove the feasibility of the concept.The PV grid interfaced systems feeding only active power into the grid are reported in. However, in this project, a multifunctional grid tied voltage source converter (VSC) is presented. The VSC in this system not only feeds the extracted solar power in to the grid but also works for reactive power compensation and harmonics mitigation for the selected loads. Some of the researchers have proposed solar PV system with active filtering capacity. Two-wire and three-wire single-phase single-stage PV systems with harmonic filtering capacity are shown in and The control algorithm in these systems is based on load power estimation. The estimated load power consists of second harmonics ripple which are inherent in single-phase systems. The estimated load power is then passed through low-pass filters for estimation of average value. The cut-off frequency of low-pass filter is kept low to estimate dc part, however, that makes the response sluggish in case of load variation. If second harmonics oscillations are not properly removed, then this cause distortion in reference grid currents.As compared to that the proposed algorithm employs a simple notch filter-based strategy and low-pass filter is avoided for estimation of load active power component. A result for extreme load variation (complete load thrown) is shown in this project to prove the feasibility of proposed control algorithm under PCC load variation. The proposed project mainly concentrates on the control algorithm for single-phase grid tied VSC. A simple notch filter-based

PLL less control algorithm is proposed to serve the aforementioned purposes. The notch filter is used in two places, one for estimation of unit vectors and the second one for the estimation of active power component of load current. The peak PCC voltage is estimated from the sensed PCC voltage and unit vectors are derived from the same which gives inherent frequency locking capacity to the system. The advantages of proposed control algorithm are simple, fast convergence, and easy tuning of internal parameters. The total harmonics distortion (THD) of grid current is observed well under IEEE-519 standard (below 5%) [24] even under nonlinear loads.

RELATED WORK

Single phase grid connected photovoltaic (PV) system operating under both grid connected and isolated grid mode. The control techniques include voltage and current control of grid-tie PV inverter. During grid connected mode, grid controls the amplitude and frequency of the PV inverter output voltage, and the inverter operates in a current controlled mode. The current controller for grid connected mode fulfills two requirements – namely, (i) during light load condition the excess energy generated from the PV inverter is fed to the grid and (ii) during an overload condition or in case of unfavorable atmospheric conditions the load demand is met by both PV inverter and the grid. In order to synchronize the PV inverter with the grid a dual transport delay based phase locked loop (PLL) is used. On the other hand, during isolated grid operation the PV inverter operates in voltage-controlled mode to maintain a constant amplitude and frequency of the voltage across the load. For the optimum use of the PV module, a modified P&O based maximum power point tracking (MPPT) controller is used which enables the maximum power extraction under varying irradiation and temperature conditions. MPPT controller is used to maximize the utiliza-tion of solar power for a given insolation and temperature condition [6, 7]. In the instantaneous maximum power point (MPP) tracking (MPPT), the PV module is operated in con-junction with a DC–DC converter. Several MPPT schemes have been proposed in the literature [7]. Some of the popular MPPT schemes are perturbed and observe (P&O), incre-mental conductance (IC), open circuit voltage, short circuit current, etc. [7, 8]. The IC method is based on the fact that,the slope of the power curve is zero at MPP, negative on the right and positive on the left of the MPP. In [9], the author claims that this method is prone to failure in case of large change in atmospheric conditions. The fractional short circuit method of MPPT is discussed in [10]. However,as this method approximates a constant ratio, its accuracy cannot be guaranteed under varying weather conditions. To overcome the above-mentioned drawbacks, several artificial intelligence based MPPT controllers have been proposed [11, 12]. But these methods also have drawbacks such as, the requirement of large data storage and extensive compu- tation. Among all the available MPPT techniques, the P&O is the most widely used MPPT scheme due to its simplicity.In [13], a review on P&O techniques has been presented. In this method the operating point oscillates around the MPP giving rise to wastage of energy.

OVERVIEW OF SOLAR ENERGY

Photovoltaic Effect

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels comprising a number of cells containing a photovoltaic material. Materials presently used for photovoltaic include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

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As of 2010, solar photovoltaic generates electricity in more than 100 countries and, while yet comprising a tiny fraction of the 4800 GW total global power-generating capacity from all sources, is the fastest growing power-generation technology in the world. Between 2004 and 2009, Grid-connected PV capacity increased at an annual average rate of 60 percent, to some 21 GW. Such installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building, known as Building Integrated Photovoltaics or BIPV for short. Off-grid PV accounts for an additional 3–4 GW.Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of photovoltaic has declined steadily since the first solar cells were manufactured. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity; have supported solar PV installations in many countries.The photovoltaic effect is the generation of a voltage (or a corresponding electric current) in a material upon exposure to light. Though the photovoltaic effect is directly related to the photoelectric effect, the two processes are different and should be distinguished. In the photoelectric effect, electrons are ejected from a material's surface upon exposure to radiation of sufficient energy. The photovoltaic effect is different in that the generated electrons are transferred between different bands (i.e. from the valence to conduction bands) within the material, resulting in the build-up of a voltage between two electrodes. In most photovoltaic applications the radiation is sunlight and for this reason the devices are known as solar cells. In the case of a p-n junction solar cell, illumination of the material results in the generation of an electric current as excited electrons and the remaining holes are swept in different directions by the built-in electric field of the depletion region. The photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839.

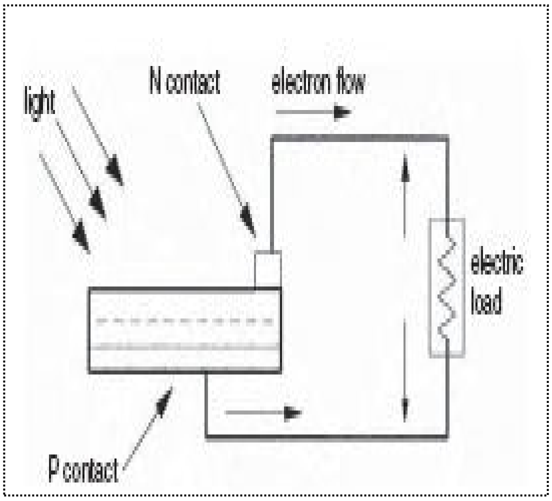
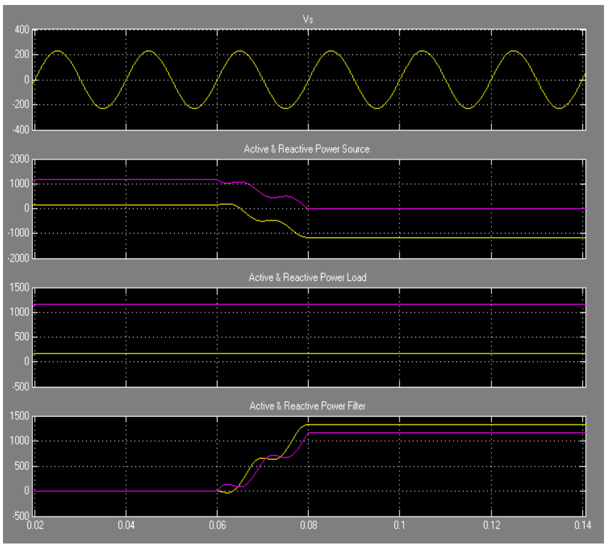


Fig 2.1: PV effect converts the photon energy into voltage across the pn junction

As of October 2010, the largest photovoltaic (PV) power plants in the world are the Sarnia Photovoltaic Power Plant (Canada, 80 MW), the Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura photovoltaic power station (Portugal, 46 MW), and the Waldpolenz Solar Park (Germany, 40 MW).

SIMULATION RESULTS



simulation results of the proposed converter under linear load conditions

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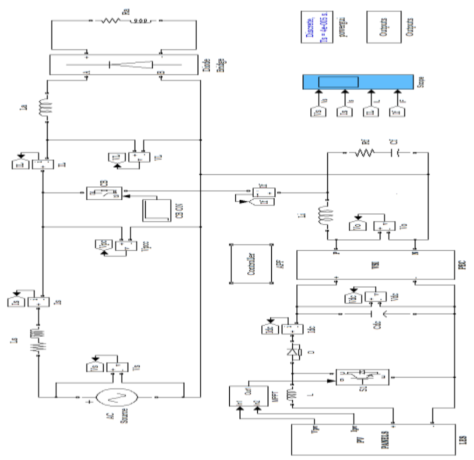
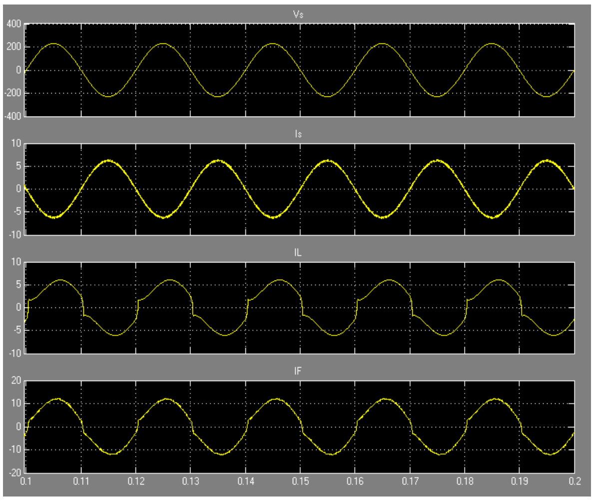
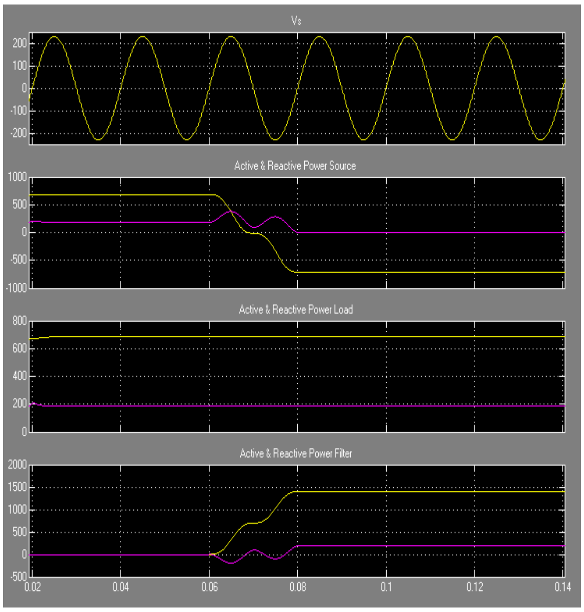
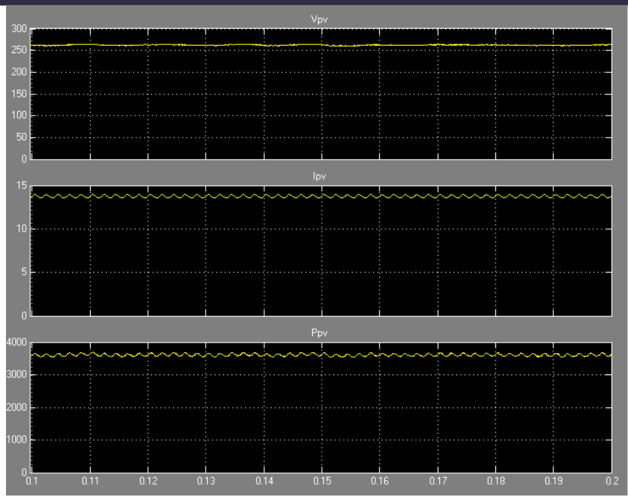


Configuration of the double-stage single-phase grid connected solar PV generating system under Non-linear load conditions





simulation results of the proposed converter under linear load conditions



simulated solar PV generating system outputs

CONCLUSION

The scheme proposed for integrating load compensation in a solar PV generation system to the single-phase grid has been realized successfully on the developed laboratory prototype. The ability of this scheme has been validated to generate the correct duty cycle for control of dc–dc boost converter, maintain a constant dc-link voltage, extract the magnitude of real component of load current, and generate a reference current using the extracted unit template of PCC voltage. The scheme has performed these operations without dependence on a PLL mechanism, and with a low calculation burden. As a result, the system has been found to extract the maximum power from solar PV array for varying solar insolation levels. It has also compensated reactive power demand of both linear and nonlinear local loads, while bringing down harmonics content of grid current in accordance with IEEE-519 standard. The system has this ability of active power filtering despite the absence of solar irradiance (cloudy day/night time).

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