A Reactive Power Compensation Method in On-Grid SPV System

Sourabh Kumar Singh[1] Yogesh Tiwari[2] Naveen Goel[3]
[1,2,3]Department of Electrical and Electronics Engineering
[1,2,3]SSGI Bhilai, CG, India

Abstract— This work presents a method to reduce reactive power in a grid connected solar photovoltaic system. The Voltage Source Inverter (VSI) is connected in between the DC link of DC-DC converter connected with the photovoltaic solar panel as the source and the grid. The control strategy used is based on theory of instantaneous reactive power theory (p-q theory). When any supply is connected to the load reactive power is generated due to the harmonics present in load at different levels of irradiance. According to this method the active power is sent to the grid and the generated reactive power is eliminated. The eligibility of the proposed method is validated in MATLAB / Simulink environment.

Keywords: Grid-Connected PV System, Instantaneous Reactive Power Theory, MPPT, Reactive Power Compensation, Power Quality

I. Introduction

In recent Scenario, the increment in electricity consumption has accelerated the need of higher power quality and improved stability. One of the major conveniences concerns is to maintain network reliability. Rising energy demand raised concerns about overloading steady state, increasing the risk of voltage failure and potential steadiness problems. As a result, rising energy consumption and the cumulative usage of nonlinear loads have generated new challenges for power stability and quality, necessitating the need for security, an efficient and reliable Alternating Power Network. Coal and other fossil fuels are expected to become extinct in the near future. In addition to general pollution, concerns such as greenhouse gas emissions, acid rain, and global warming have emerged. As a result of environmental regulations and a serious lack of traditional energy sources, renewable energy has already become increasingly appealing. Solar Photovoltaic (SPV) generation is a technology for converting solar energy into electrical energy by using photovoltaic cells. Due to its obvious advantages, such as simple construction, easy allocation, pollution-free, low maintenance cost, and so on, photovoltaic is becoming increasingly essential as a source of renewable energy in site. The design of a solar system utilizing a basic circuit model is provided in this study, along with comprehensive modelling of photovoltaic module circuits. The physical equations that regulate the PV module (which also apply to PV cells) are presented. Simulations were used to verify the behavior of the circuit model generated using the DC-DC boost converter [1]. The theory of instantaneous reactive power (PQ theory), which governs the active and reactive power at the inverter output, is proposed in this study. The experimental verification of simulation findings is shown here. This work also offers to use MATLAB/Simulink software to create a pv modelling system with maximum power point tracking (MPPT) function in order to model, e.g. The first model of the most significant component of a photovoltaic system, the solar module, has been developed. Under various temperature and irradiance settings, the properties of the developed solar module model were simulated and compared to those of the actual field test data. Following that, a photovoltaic system model with maximum power point tracker (MPPT), The perturbation and observation approach was used to construct a DC-DC buck-boost converter, which was then developed and simulated.

II. Proposed System Model Description

For the study of the proposed system, expertise of mathematical models that represent the electrical values at the output of the Photovoltaic panel and solar cell is necessary [11].

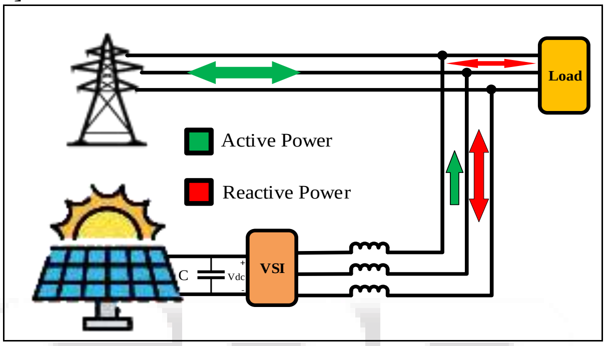

Fig. 1: Proposed Grid Connected PV System

A. Equivalent Circuit of PV Modelling

A PV array is made up of many PV cells that are wired in series and parallel. The greater voltage of the module is caused by serial connections, but the increased flow of current in the matrix is caused by parallel connections [7]. A solar cell may generally be approximated by a solar cell, as seen in Fig. 2. In reverse parallel, a current source and a diode are linked. It has its own resistance in series and parallel [5]. The barrier to the flow route of electrons at the output P causes series resistance, whereas the leakage current causes parallel resistance.

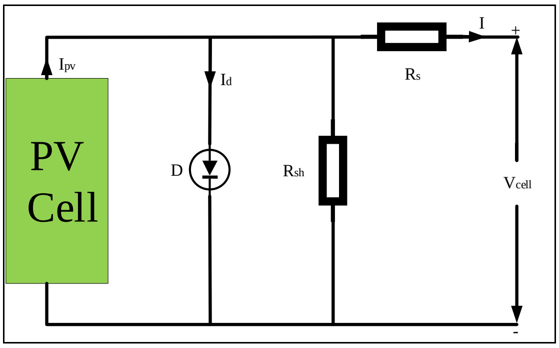

Fig. 2: Mathematical Model of PV

Using the PV model, the current-voltage relationship of the PV cell is represented by the equations used in [5].

I_o is the reverse saturation or leakage current of the diode, where I_{pv} is the current generated by incoming light (it is directly proportional to the sun irradiation).

B. MPPT Algorithm

MPPT algorithms are essential in PV applications because the MPP of a solar panel fluctuates with irradiance and temperature, necessitating the employment of MPPT algorithms to get the most power out of a solar array. Perturbation and Observation (P&O) is utilised in this study [8]. It's the most often utilised algorithm. The MPP is tracked using this approach, which involves perturbing the duty ratio of the boost converter on a regular basis depending on the slop of the power-voltage (P-V) curve. If the duty ratio perturbation increased the power, the following perturbation sign remains the same; otherwise, it is modified. This procedure is repeated until MPP has been attained.
The P&O algorithm's flowchart is presented in Fig. 3.

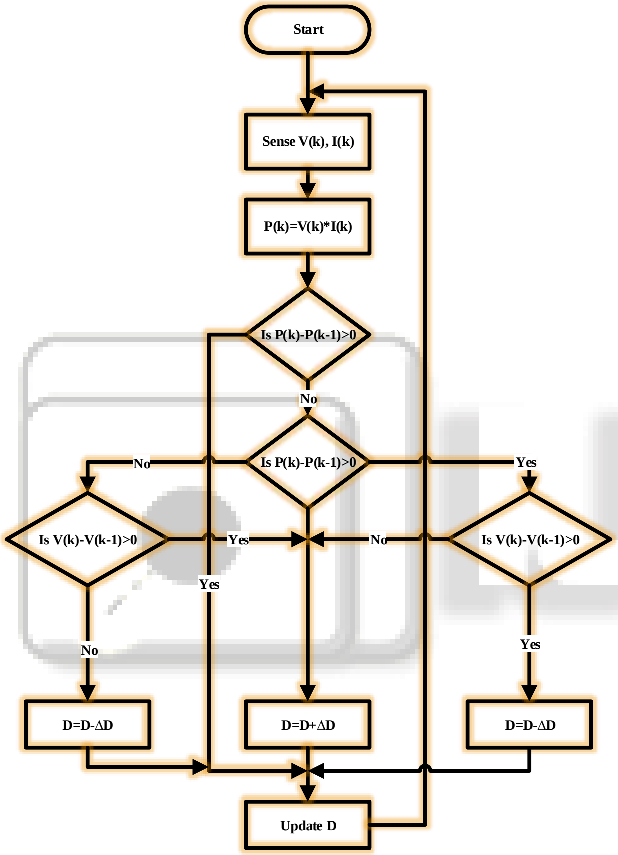

Fig. 3: MPPT flow chart

III. CONTROL STRATEGY OF GRID CONNECTED PV SYSTEM

The “instantaneous reactive power theory” (P-Q theory) is utilized to regulate the grid-connected PV system's control strategy, and the hysteresis band control approach is utilized to regulate the inverter output current [9]. Figure 4 shows a block schematic of the proposed grid-connected PV system's control approach.

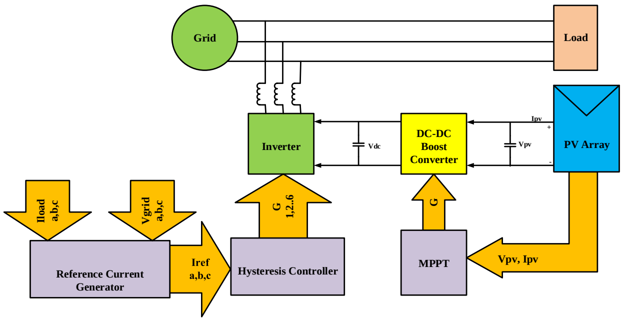

Fig. 4: Block diagram of control strategy of PV system

The PV inverter regulates the amount of active and reactive electricity that is injected. To compensate for load harmonics and reactive power, the PV inverter is also employed as an active power filter.

A. Active Power Control

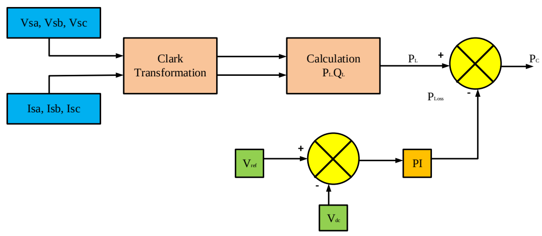

Fig. 5: Block diagram of Inverter’s active power control

Some losses in the circuit are produced by the voltage source converter's switching action (as above). When the PV runs and sends active Power to the grid, the losses are compensated by the solar system [10], as shown in the block diagram of Fig. 5. The losses are compensated by the investor network during the time when the PV system is producing active power.

B. Reactive Power Control

The instantaneous imaginary power q corresponds to the instantaneous reactive power [13], which is introduced by the p-q hypothesis. According to theory, the inverter supplies the load with instantaneous reactive power, which is provided by the equation p-q:

C. Reference Current Generation

The p-q theory, which is based on instantaneous active and reactive power, uses the equation to compute reference currents in the - system.

Using the equation's reverse transformation. The reference currents in the ABC system of coordinates may be calculated using the following equation [13].

D. Current Control

Control of the Present As shown in figure 4.8, the hysteresis band current control approach is used to regulate the inverter output current. A band is created in the hysteresis current control approach, within which the inverter current strives to stay close to the reference currents [9]. The control approach has the advantages of being relatively simple, having excellent dynamic behavior, and having a quick reaction time.

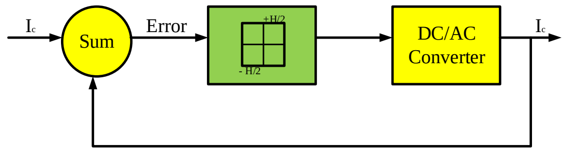

Fig. 6: Block diagram of hysteresis band current control technique

The inverter's actual output current is compared to the tolerance band around the reference current associated with that phase for a sinusoidal reference current. The lower switch of phase A of the inverter is switched on and the upper switch is turned off if the actual current tries to exceed the upper tolerance band. If the real current tries to go below the lower tolerance band, the phase A switches to the other direction. The switching phases B and C are calculated in the same way.

IV. SIMULATION RESULTS

The proposed Photovoltaic cells are not only capable of supplying extracted solar power to the power system, but it also can significantly compensate the reactive power and mitigate harmonic currents which are drawn by non-linear loads. In order to demonstrate the validity of the concepts discussed previously in Fig. 4, the simulation using MATLAB/SIMULINK. Represented in the Fig. 7, simulation model work of grid connected PV system. A 255.02 Kw PV array system is designed as using SunPower SPR-WHT-D PV module simulation as per Table I. In the Table II shows the parameters of electrical power system used in the simulation. The reference DC link voltage is 700 volts and three phase ac side line to neutral is 230 volts.

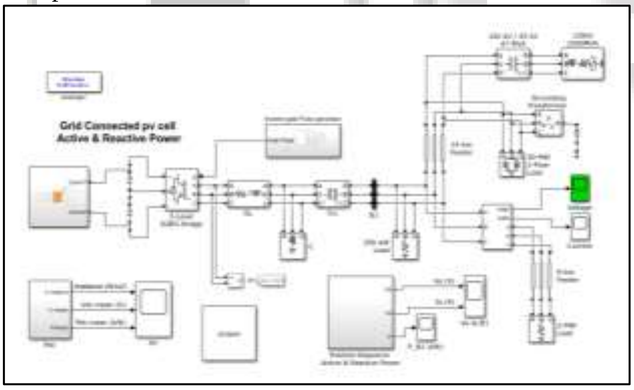

Fig. 7: Simulation model of developed On-grid SPV system.

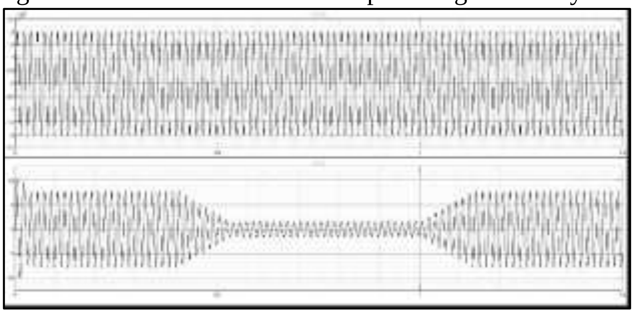

Fig. 8: Positive and negative sequence of active and reactive power

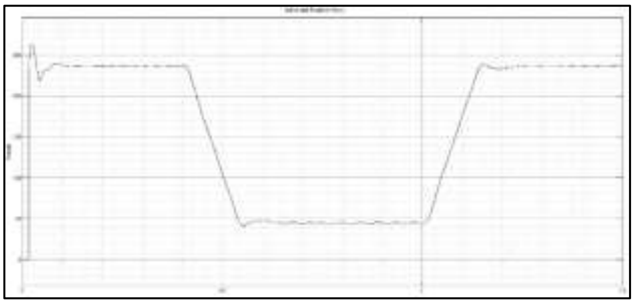

Fig. 9: Variation in DC power of SPV system

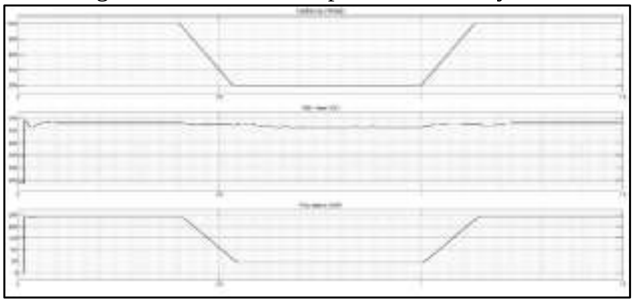

Fig. 10: Variation of output DC power of SPV system

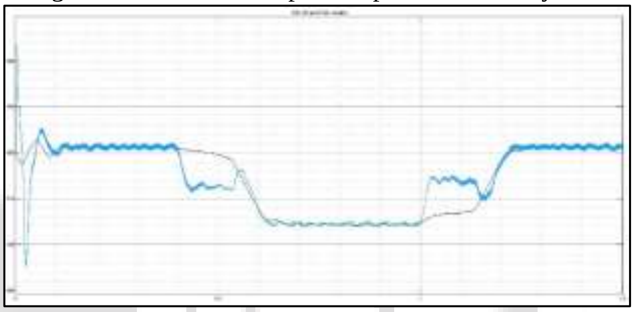

Fig. 11: Variation of gate pulse for controlling Inverter circuit.

V. CONCLUSION

Photovoltaic power seems to be the favorable clean energy source of the future. So, to optimize its use we have proposed a direct coupling of PV system to the grid. From the results obtained, it is proven that by using the proposed system, Photovoltaic power can be efficiently extracted by solar cells and injected into the grid and compensating reactive power of the load all 24 h of the day. The proposed system also compensates the harmonics content of nonlinear load. Finally, and according to the obtained results we can consider the proposed system to be efficient solution to the growing demand of power at the present and in the future.

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