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Analysis of Active & Reactive Power Flow in Photovoltaic Energy Connected To Distribution Grid

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ABSTRACT: In this paper, the design of photovoltaic system using simple circuit model with detailed modelling of photovoltaic modules circuit is presented. This paper also proposes to develop a photovoltaic simulation system with maximum power point tracking (MPPT) function using MATLAB/Simulink software in order to simulate, evaluate and predict the behaviours of the real photovoltaic system. The voltage source inverter (VSI) is coupled between the dc output of photovoltaic system and ac grid. The control technique applied is based on theory of instantaneous reactive power (p-q theory). According to this, proposed PV system used to deliver active power to the grid at the same time, the reactive power of load and harmonics will eliminate at change in both irradiation and load condition. During no sunlight, system is available only with reactive power and harmonic compensation. The applicability of our system tested in simulation in MATLAB/Simulink.

KEYWORDS: Grid Connected Photovoltaic, Reactive Power Compensation, MPPT, VSI, Power Quality.

I.INTRODUCTION

One in recent decades, the development of the electricity market has accelerated the use of higher power quality and improved stability. Rising energy transfers raise relates about overloading steady state increasing the probability of voltage collapse and potential stability issues. Therefore, the growing demand for electricity and the increasing use of nonlinear loads have created new challenges for the power quality and stability that lead to the need for security, the network of efficient and clean AC. Energy reserves, such as coal, are likely to be extinct in the near future oil. In addition to the average environmental pollution has led to problems such as emissions of greenhouse gases, acid rain and global warming. So, renewable energy has become increasingly attractive due to the rules of environmental protection and the severe shortage of conventional energy sources. Photovoltaic (PV) generation is the technique that uses photovoltaic cells to convert solar energy into electrical energy. Photovoltaic is assuming increasingly important as a source of renewable energy in place due to its clear advantages, such as simple architecture, easy allocation, pollution-free, low maintenance cost, and etc.In this paper, the design of photovoltaic system using simple circuit model with detailed modelling of photovoltaic modules circuit is presented. The physical equations supervising the (also applicable to PV cells) PV module presents. The operation of the circuit model developed with DC to DC boost converter was verified with simulations. This paper proposes the use of the theory of the instantaneous reactive power (PQ theory), which controls the active and reactive power at the inverter output. Here presents the experimental verification of simulation results. This paper also proposes to develop a photovoltaic simulation system with maximum power point tracking (MPPT) function using MATLAB/Simulink software in order to simulate, evaluate and predict the characteristics of the real photovoltaic system. A model of the most useful component in the photovoltaic system, the solar PV module, is the first to have been established. The performance aspects of the established solar module model were simulated and compared with those of the original field test data under different temperature and solar irradiance conditions. After that, a model of a photovoltaic system with maximum power point tracker (MPPT), which was developed using DC-DC buck-boost converter with the perturbation and observation method, was then established and simulated.

II.SYSTEM MODEL AND ASSUMPTIONS

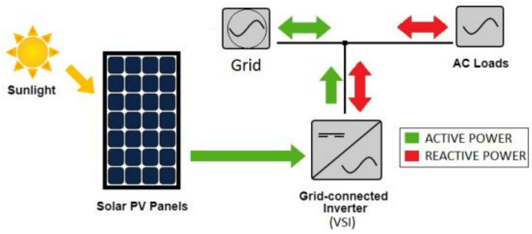

Fig. 1. Proposed Grid Connected PV System

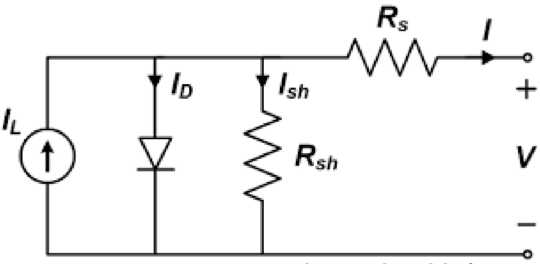

Fig. 2. Mathematical Model of PV

The preferred system is shown in Fig.1 for analysis of the system's knowledge of the mathematical models and equations that reflect the electrical quantities at the output of the solar PV panel and solar cell is required.

A. Equivalent Circuit of model PV:

A PV array consists of several PV cells connected in series and in parallel. Serial connections are responsible for the higher voltage of the module, while the parallel connection is responsible to increase the flow in the matrix.

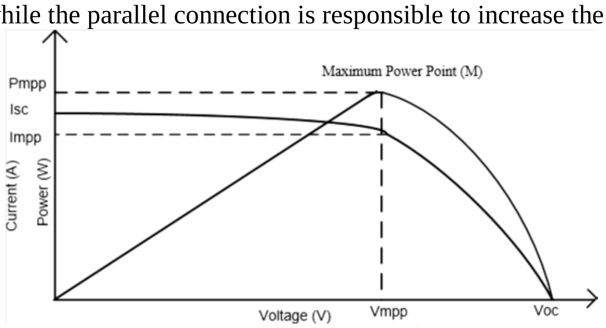

Fig. 3. P-V and I-V characteristics of PV array

As shown in Fig. 2, typically, a solar cell can be modelled by a current source and a diode connected in reverse parallel. It has its own series and parallel resistance. Series resistance is due to the barrier to the flow path of electrons output 'P and 'N parallel resistance is due to the leakage current.The P-V and I-V Characteristics are shown in Fig.3.The I-V relation of the PV cell using PV model is represented by following equations.

$$I = I_{pv} - I_0\left(e^{\left(\frac{q(V+IR_S)}{nkT}\right)-1}\right) - \frac{V+R_S I}{R_p} \quad \ldots(1)$$

$$I_{pv} = I_{pvn}\left(1 + K_i(T - T_1)\right)\frac{G}{G_n} \quad \ldots(2)$$

$$I_0 = \frac{\left(I_{scn} + \left(K_i(T - T_1)\right)\right)}{e^{\frac{\left(V_{ocn} + K_v(T - T_1)\right)}{(aVt)}} - 1} \quad \ldots(3)$$

Where,

I_{pv} - Current generated by the incident light (it is directly proportional to the sun irradiation),

I_o - Reverse saturation or leakage current of diode.

B. MPPT Algorithm:

MPPT algorithms are necessary in PV applications because the maximum power point of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar PV array. In this simulation, Perturbation and Observation (P&O) technique is used. It is most commonly used algorithm. In this method, the maximum power point is tracked by perturbing the duty ratio of boost converter at a regular interval based on the slop of power-voltage (P-V) curve. If the perturbation in duty cycle ratio increased the power than the next perturbation sign is equal otherwise perturbation sign is changed. This process is repeated until maximum power point is reached.The flowchart of the P&O algorithm is given in Fig. 4.

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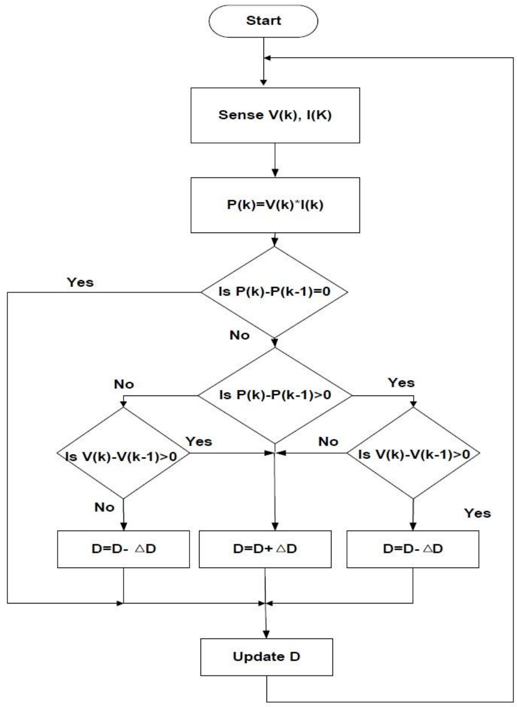

Fig. 4. MPPT flow chart

III.CONTROL STRATEGY OF GRID CONNECTED PV SYSTEM

For the control strategy of the grid-connected solar PV system "instantaneous reactive power theory" (P-Q theory) is applied and for control inverter output current the hysteresis band control technique is used. Block diagram of control technique for proposed grid connected PV system shown in the Fig.5.

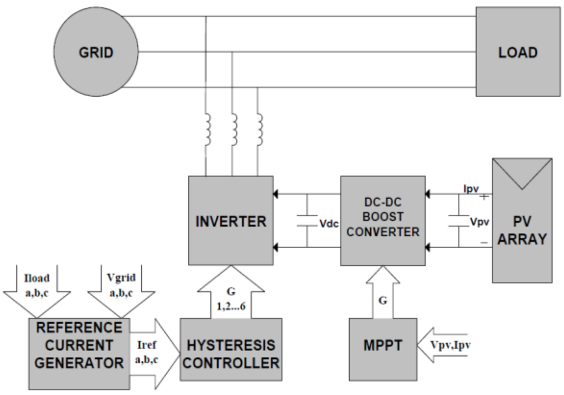

Fig. 5. Block diagram of control strategy of PV system

The solar PV inverter injects the active power and reactive power in controlled manner, hence the system is compensated. The PV inverter is also used utilized as an active power filter to compensate the load harmonics and reactive power. The basic Simulink model of control technique for proposed grid connected PV system shown in the Fig.6.

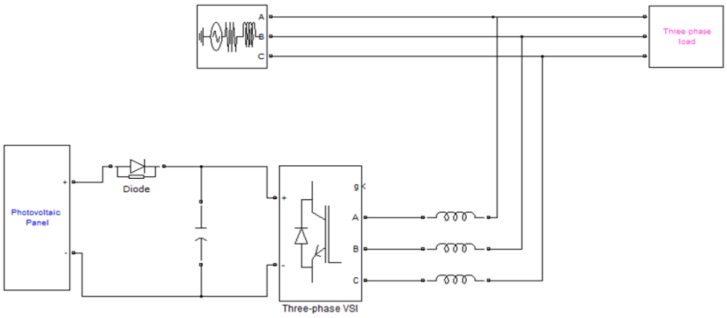

Fig. 6. Simulink Model of PV System and Three Phase Load Connected to3-phase Supply Voltage 230V (phase) and 50 Hz

A. Active Power Control:

Due to the switching operation of the voltage source converter, some losses are caused in the circuit (as above). According to the block diagram of Fig. 7, the losses are covered by the solar system when the PV operates and supplies the active Power to grid. During the period when the PV system produces active power, then the losses are covered by the investor network.

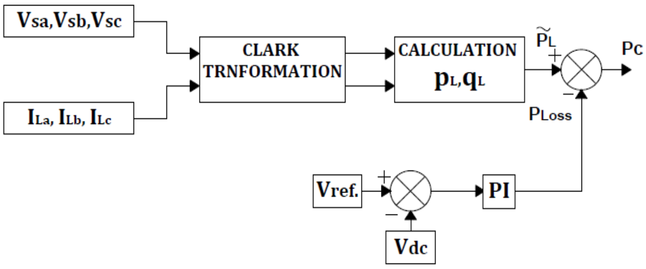

Fig. 7. Block diagram of Inverter's active power control

B. Reactive Power Control:

The p-q theory introduces a new variable, which is the instantaneous imaginary power q corresponds to the instantaneous reactive power. Instantaneous reactive power with the inverter feeds the load is given according to the theory by the following equation p-q.

$$q = V_{s\alpha} I_{l\beta} - V_{s\beta} I L_{\alpha} \qquad \ldots(4)$$

C. Reference Current Generation:

The p-q theory based on the instantaneous P & Q power, calculates reference currents in the α-β system according to the equation.

$$\begin{bmatrix} I_{c\alpha} \\ I_{c\beta} \end{bmatrix} = \frac{1}{V_{s\alpha}^2 - V_{s\beta}^2} \begin{bmatrix} V_{s\alpha} & V_{s\beta} \\ V_{s\beta} & -V_{s\alpha} \end{bmatrix} \begin{bmatrix} \widetilde{P_L} - P_{loss} \\ -q \end{bmatrix} \qquad \ldots(5)$$

Using the reverse transformation of the equation, we can calculate the reference currents in the ABC system of coordinates according to the following equation.

$$\begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{c\alpha} \\ I_{c\beta} \end{bmatrix} \qquad \ldots(6)$$

D. Current Control:

The hysteresis band current control technique is applying to control the inverter output current as Shown in the Fig.8.

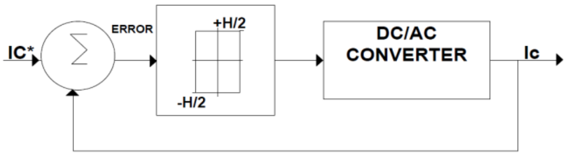

Fig. 8. Block diagram of hysteresis band current control technique

In the hysteresis current control method, a band is define, within which the inverter current tries to keep around the reference currents. The advantages of the control technique are very simple, very good dynamic behaviour and fast response. For a sinusoidal reference current, the inverter actual output current is compared with the tolerance band around the reference current associated with that phase. If the actual current tries to go beyond the upper tolerance band, lower switch of phase A of inverter is turned on and upper switch is turned off. The opposite switching occurs for the phase A if the actual current tries to go below the lower tolerance band. The switching of phase B and C can be determined similarly.

IV.ADVANATAGES

- Effective power flow due to MPPT.
- Simultaneous voltage and current quality improvement.
- Integration of clean energy generation and power quality improvement.

V.APPLICATIONS

- In optimization of standalone systems.
- Utility grid interactive applications.
- Improving power quality at Non-Linear loads.

VI.CONCLUSION

Thus it is clear that the solar PV system injects appropriate amount of current to mitigate harmonics generated by the nonlinear loads and reactive power compensate at the same time, it delivers the excess active power to the grid. Photovoltaic power seems to be the favourable clean energy source of the future. In order to optimize its usage, we have proposed a direct coupling of solar PV system to the grid.

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