ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 5, May 2014

Novel Control Strategy For Grid-Connected PV System With Reactive Power Compensation And MPPT Control

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Abstract: A PV system connected to the network with the functionality of the reactive power compensation and harmonic is introduced in this paper. The output of the PV system varies due to changes in solar irradiance and climate conditions. PQ theory can be used to control the VSC, which is independent of the control of the maximum power point of the buck / boost dc / DC converter. Then the VSC is used to interact with the electric grid through the network. Increasingly, the use of static power converter and switching mode power consumption injected current harmonics and reactive power in the electrical system. It will be shown that the VSC can be controlled to compensate the harmonic current and supplying active and reactive power. The harmonic current is extracted by using the theory of PQ. According to this strategy of sunlight during the active system sends power to the grid and also compensates the reactive power of the load and compensate harmonics. If there is no sunlight, the inverters compensates the reactive power and harmonic load and greatly improve the power factor of the installation. The proposed control strategies validated using MATLAB Simulink system/ Simpower.

Keywords: Grid-connected PV system, Instantaneous reactive power theory, MPPT, Reactive power compensation, Power quality.

I. INTRODUCTION

In recent decades the development of the electricity market has accelerated the use of higher power quality and improved stability. One of the major utilities concerns of is maintain network reliability. Rising energy transfers raise concerns about overloading steady state increasing the risk of voltage collapse and potential stability problems[5]. 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, is 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 modeling of photovoltaic modules circuit is presented. The physical equations governing 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 behaviours of the real photovoltaic system. A model of the most important component in the photovoltaic system, the solar module, is the first to have been established.

The characteristics of the established solar module model were simulated and compared with those of the original field test data under different temperature and 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.

A. PROPOSED SYSTEM DESCRIPTION

The proposed system is shown in Figure 1. For analysis of the system's knowledge of the mathematical models that reflect the electrical quantities at the output of the photovoltaic panel and solar cell is required.

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Vol. 2, Issue 5, May 2014

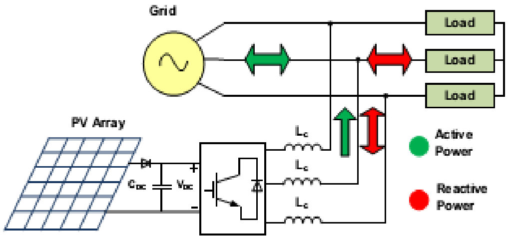

Fig. 1 Grid connected Photovoltaic system

B. EQUIVALENT CIRCUIT OF PV MODELING

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[1]. Typically, a solar cell can be modeled 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 impediment to the flow path of electrons output P and N parallel resistance is due to the leakage current.

The advantage of this control method is that it introduces simple algebraic calculations and does not require the use of PLL to synchronize the PV system to the network. According to voltages "instantaneous reactive power theorem" and load currents are transformed from abc coordinate reference system α-β coordinate reference system (Clark transformation) This transformation is shown in Fig.4.

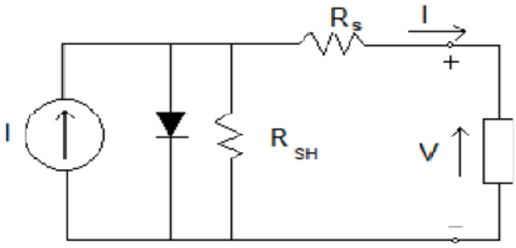

Fig.2 Single diode model of a PV cell

The photo current I_{ph} depends on solar radiation G and temperature T of the environment[9]. In the photovoltaic system would work the temperature is equal to the nominal, and the photo current I_{ph} depend only on solar radiation according to equation (1):

$$I_{ph} = I_{ph(ref)} = \frac{G}{G_{ref}} I_{ph(ref)} \qquad (1)$$

Where T_{ref} is the reference temperature, G_{ref} is the nominal solar radiation and I_{sc} is the short circuit current. For a photovoltaic cell its output current is:

$$I_{PV} = I_{ph} - I_0\left[\exp\frac{V_{pv}+I_{ph}R_s}{VT} - 1\right] - \left[\frac{V_{pv}+I_{ph}R_s}{R_{SH}} - 1\right] \qquad (2)$$

Where and are PV cells output current and voltage correspondingly, I_o is saturation current diode, V is thermal voltage.

$$I_{pv} = pI_{ph} - pI_0\left[\exp\frac{V_{pv}+\frac{s}{p}R_s}{sVT} - 1\right] \qquad (3)$$

And its output voltage is:

$$V_{pv} = sV_T \cdot \log\left[\frac{pI_{ph} - I_{PV}}{p \cdot I_0} - 1\right] - I_{ph} \cdot \frac{s}{p} \cdot R_s \qquad (4)$$

$$P_{pv} = V_{pv} I_{pv} \qquad (5)$$

C. CONTROL STRATEGY OF GRID CONNECTED P/V SYSTEM

For the strategy to control networked P / V system PQ theory is applied. To control the output current of the inverter current control technique applies hysteresis band [1]. The variables we measure are the output of PV main's voltages feed capacitor voltage V_{dc} shown. Control of active and reactive power is based on the "theorem of instantaneous reactive power". Figure 3 shows a block diagram of control and training strategy proposed feeding system[9].

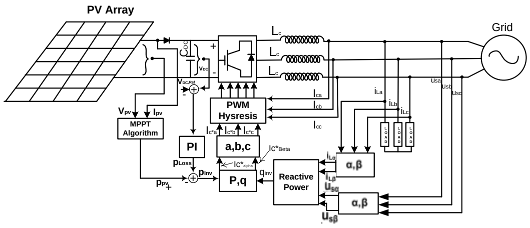

Fig.3 Block diagram of control strategy of PV system

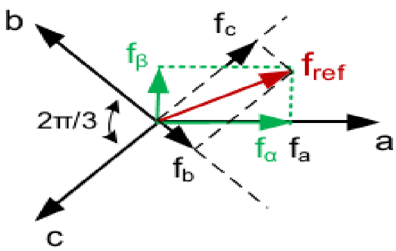

Fig.4 Transformation from a-b-c into α-β coordinates System

The mathematical relationships of the load current and voltages in the two different coordinate systems are given by equations (6) and (7) respectively:

$$i_{L,\alpha\beta} = M i_{L,abc} \qquad i_{L,abc} = M^{-1} i_{L,\alpha\beta} \qquad (6)$$

$$u_{s,\alpha\beta} = M u_{s,abc} \qquad u_{s,abc} = M^{-1} u_{s,\alpha\beta} \qquad (7)$$

Where,

$iL,\alpha\beta = [\, iL\alpha\, iL\beta\,]T$,$us,\alpha\beta = [\, u_{s\alpha} u_{s\beta}\,]T$,

$iL,abc = [\, iLaiLbiLc]T$, $us,\alpha\beta = [\, u_{sa} u_{sbusc}]T$ (8)

is the matrix of Clark transformation and equals to:

$$M = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}} \end{bmatrix}, \mathbf{M^{-1}} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \sqrt{\frac{3}{2}} \\ -\frac{1}{2} & -\sqrt{\frac{3}{2}} \end{bmatrix}$$

$M = M^{-1}$ because matrix M is an orthogonal matrix

D. MAXIMUM POWER POINT TRACKING(MPPT) THEORY

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The main purpose of this work is to develop a system of tracking simulation with photovoltaic maximum power point of the function (MPPT) using software Matlab / Simulink to simulate, evaluate and predict the behavior of the actual PV system[11]. After that, I was then established and simulated a model of a photovoltaic system with maximum power point tracker, which was developed using DC -DC buck-boost converter with the perturbation method and observation.

In order to improve the production efficiency of photovoltaics, A novel variable step size perturbation and observation P & O method is proposed to track the maximum power point of the PV system[12]. Based on the mathematical model of the photovoltaic system , this method is the maximum power point by regulating the output voltage after measuring changes in output power. The simulation model of the photovoltaic system is established and the experiment was conducted. Experimental results show that the method can track the point of maximum power rapidly and accurately, demonstrating that adaptive P & O have a better steady state and dynamic performance than the traditional P & O, and can improve the efficiency of photovoltaic power generation effectively.

Due to various external conditions (light intensity, temperature and load characteristics) and its influence factors, the output characteristics of photovoltaic power generation are obvious nonlinear [11].Under certain conditions of light intensity and temperature of the environment, the output power change of the PV cell voltage and appears as a single convex curve.

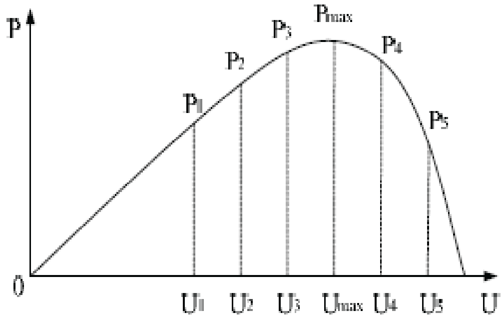
Photovoltaic cell maximum power exported only when working on the apex of the curve, which is known as the maximum power point. As changes of maximum power point with light intensity and temperature, the key to improving the overall efficiency of the PV system is the real-time adjustment of photovoltaic cells operating point in the vicinity of the maximum power point, called maximum power point tracking (Maximum Power Point Tracking, MPPT).

Two Common Methods of Maximum Power Point Tracking

1. Incremental Conductance Method
2. Perturbation and Observation, P&O

Here explained Perturbation and Observation, P&O:
Perturbation and Observation Method (Perturbation and Observation, P & O), is also known as hill climbing method (Hill Climbing, HC). Its working principle is making a small active voltage perturbation in a certain working voltage of photovoltaic cells and observing the change direction of output power.

If the output power increases then perturbation in the same direction should be kept, otherwise perturbation against the original direction should be made. The tracking diagram of perturbation and observation method is as follows:



Tracking schematic diagram of the perturbation and observation method

Disturbance observation has been widely used in photovoltaic maximum power point tracking because of its simple control structure, few parameters, and easy implementation. However, due to its fixed step, the oscillation phenomenon occurs near the maximum power point, which reduces the power generation efficiency.

Reducing the magnitude of each adjustment can weaken to a certain extent the oscillation near maximum power point, but the tracking to changes in the external environment will slow down, which also reduces the power efficiency. Therefore, selecting the appropriate step is the key for perturbation and observation method to achieve the desired effect.

E. REACTIVE POWER CONTROL

PQ 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 PQ:

$q = u_{s\alpha} i_{L\beta} - u_{s\beta} i_{L\alpha} = [us\beta \quad us\alpha]$

F. ACTIVE POWER CONTROL

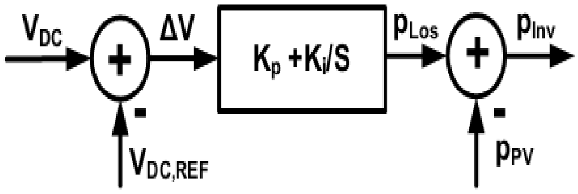


Fig.5 Block diagram of Inverter's active power control

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 Figure (top left), the losses are covered by the solar system when the P / V operates and supplies the active Power grid with. During the period when the PV system produces active power, then the losses are covered by the investor network

G. REFERENCE CURRENT GENERATION

The PQ theory based on the instantaneous active and reactive power, calculates reference currents in the α-β system according to the equation (9)

$$\begin{bmatrix} i*_{c,\alpha} \\ i*_{c,\beta} \end{bmatrix} = \frac{1}{u^2_{s,\alpha}+u^2_{s,\beta}} \cdot \begin{bmatrix} u_{s,\alpha} & u_{s,\beta} \\ u_{s,\beta} & -u_{s,\alpha} \end{bmatrix} [-p_{pv} \quad \pm p_{pv} \quad -q] \qquad (9)$$

Using the reverse transformation of the equation We can calculate the reference currents in the ABC system of coordinates according to the following equation:

$$\begin{bmatrix} i*_{c,\alpha} \\ i*_{c,\beta} \\ i*_{c,c} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \sqrt{\frac{3}{2}} \\ -\frac{1}{2} & -\sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} i*_{c,\alpha} \\ i*_{c,\beta} \end{bmatrix}$$

H. CURRENT CONTROL

To control the inverter output current control technique apply current hysteresis band, shown in Figure 6. With this method a region around the reference current trying to keep the output current of the inverter within this zone is created. The advantages of the technique of controlling the hysteresis band are its simple application. It's very good dynamic behaviour and rapid response.

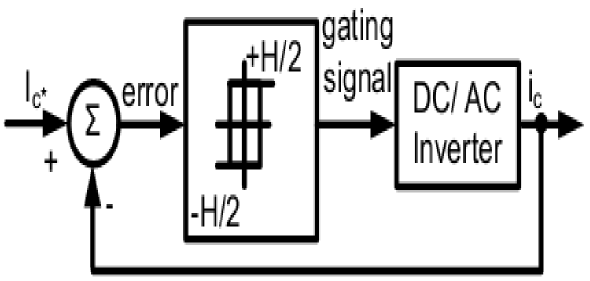


Fig.6 Block diagram of hysteresis band current control technique

The hysteresis band current control sets the time and duration of each pulse. The logic of the witches for phase "a" is summarized as follows:

If the inverter output current reaches the upper limit of the zone, then the upper switch is off and the bottom switch is ON. If the inverter output current reaches the lower limit of the zone, then the upper switch is ON and lower switch is off. The switching phase "b" and "c" are determined similarly.

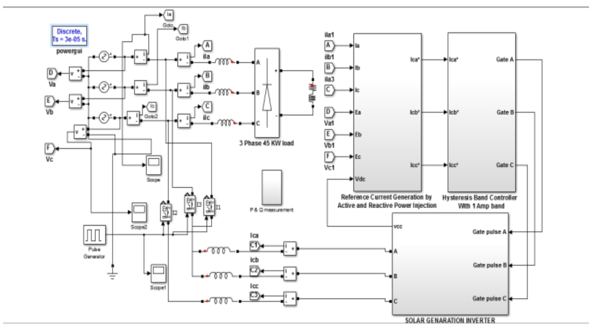


Fig.7 Model of three phase grid connected active and reactive power control by using p-q theory with mppt

I. SPECIFICATIONS OF SOLAR PV CELL

Description	Parameter
Number of P/V panel in series	7
Number of P/V panel in parallel	6
Open circuit voltage per panel	64.2 V
Short circuit voltage per panel	5.96 V
Reference solar irradiation	1000 W/m²
DC bus capacitor	4000µf
Inductance	3 mH
Maximum output voltage per panel(V_{mp}) in Volt	54.7 V
Maximum output current per panel (I_{mp}) in Ampere	5.58 A
Total output voltage of PV Array in Volt	382.9 V
Total output Current of PV Array in Ampere	33.48 A
Grid Voltage (Per Phase)	230 V
Frequency in Hz	50 Hz

J. SIMULATION RESULTS

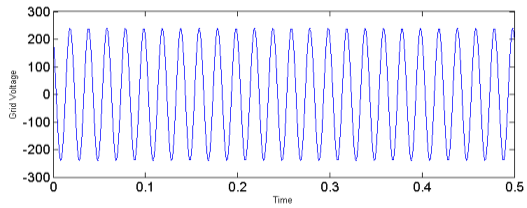


Fig.8 Grid voltage waveform

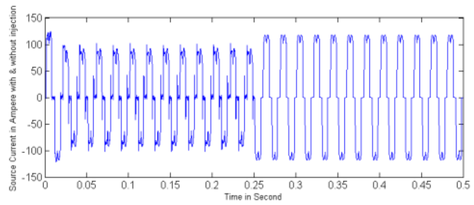


Fig.9 Source Current in amperes with and without compensation at irradiation 1000 w/m²

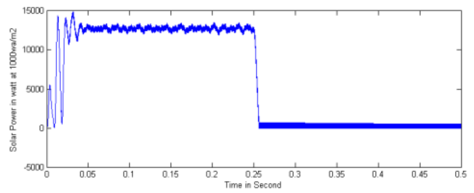


Fig.10 Solar Power in watt at Irrediation 1000 w/m²

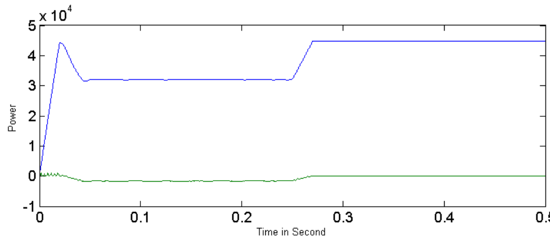


Fig. 11 Active (Blue Colour) and Reactive Power (Green Colour) with compensation and without compensation

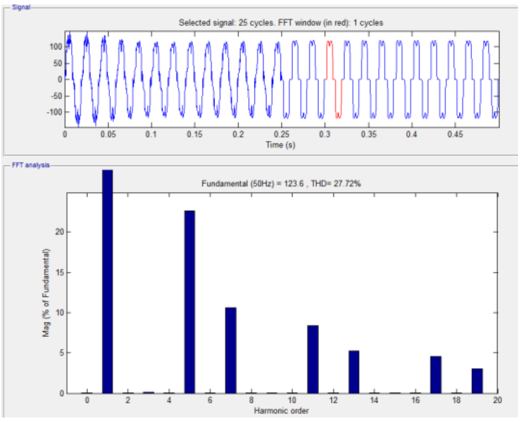


Fig. 12 THD Analysis Before the Reactive Power compensation

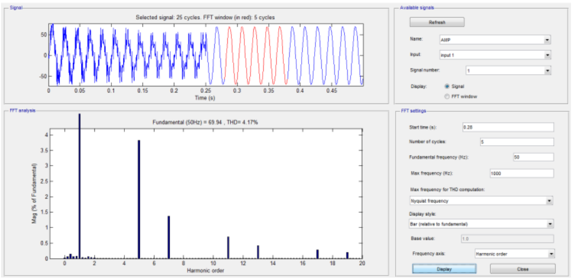


Fig. 13 THD Analysis After the Reactive Power compensation

II. CONCLUSION

In this paper we can conclude that it would prove that the VSC can be controlled to compensate the harmonic current and the supply of active power and reactive power. The harmonic current is extracted by using the theory of PQ. According to this strategy of sunlight during the active system sends power to the grid and also compensates the reactive power of the load and compensate harmonics. If there is no sunlight (overnight, for example), only the inverter compensates the reactive power and harmonics load. And greatly improve the power factor of the installation. Indicates that the control method of working, even if the load current contains harmonic components.

REFERENCES

[1] "Grid-connected photovoltaic power systems: Technical and potentialproblems"—A review by- Mohamed A. Eltawila,b, Zhengming Zhao [1]
[2] "A Single-Phase Voltage-Controlled Grid-Connected Photovoltaic System With Power Quality Conditioner Functionality" by-Rosa A. Mastromauro,Member, IEEE, Marco Liserre, Senior Member, IEEE,TamasKerekes,Student Member, IEEE, and Antonio Dell'Aquila, Member, IEEE [2]
[3] "Three Phase Grid Connected Photovoltaic System with Active and Reactive Power Control Using Instantaneous Reactive Power Theory" by-G. Adamidism, G.Tsengenesand K. Kelesidis [3]
[4] "Phase Coordinate System and p-q Theory Based Methods in Active Filtering Implementation" by- Mihaela POPESCU, Alexandru BITOLEANU, Vlad SURU University of Craiova, Faculty of Electrical Engineering, Craiova, 200440, Romania [4]
[5] "Application of circuit model for photovoltaic energy conversion system" by- Pandiarajan N, Ramaprabha Rand Ranganath Muthu, Associate Professor, Department of Electrical & College of Engineering, Kalavakkam - 603110, Indiapandiarajann@ssn.edu.in [5]
[6] "Modeling and simulation based approach of photovoltaic system in simulink model" by- M. Abdulkadir, A. S. Samosir and A. H. M. Yatim [6]
[7] "Analysis of Different Real Time Reference Generation Techniques used for Harmonic Mitigation in Three Phase Shunt Active filters" by- Naimish Zaveri, Ajitsinh Chudasama [7]
[8] "Application of Circuit Model for Photovoltaic Energy Conversion System" by- Natarajan Pandiarajan, Ramabadran Ramaprabha, and Ranganath Muthu-Research Article [8]
[9] "Instantaneous power theory and applications to power conditioners". A book by – Akagi [9]
[10] "MATLAB-based Simulation of Photovoltaic Solar Cell and its Array at Different Temperature values" by-H.G.Bhatt, R.A.Thakker [10]
[11] "Matlab/Simulink-Based Research on Maximum Power Point Tracking of Photovoltaic Generation" by-Lijun Qin,Xiao Lu Academy of Modern Electric Power Research North China Electric Power University, NCEPU Beijing, P.R.China International Conference on Applied Physics and Industrial Engineering, 2012 [11]
[12] "Analysis and Simulation of Characteristics and Maximum Power Point Tracking for Photovoltaic Systems" by-Ting-Chung Yu Member, IEEE Department of Electrical Engineering Lunghwa University of Science and Technology Taoyuan, Taiwan, R.O.C. tingyu@mail.lhu.edu.tw [12]