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Improvement of Power Quality by Current Controller for Grid Connected PV System

S. Rajendra prasad[1], K. B. Madhu sahu[2], CH. Krishna rao[3]
[1]*P.G Student, Dept. of EEE, AITAM Engineering college, AP, India, rajendra29.eee@gmail.com*
[2]*Professor, Principal, Dept. of EEE, AITAM Engineering college, AP, India, kbmadhusahu@gmail.com*
[3]*Associate Professor, Dept. of EEE, AITAM Engineering college, AP, India, krishnarao.chala@gmail.com*

Abstract- This paper presents power quality on grid connected PV systems consists of solar PV array, DC-DC boost converter, maximum power point tracking (MPPT), Voltage source inverter(VSI), current controller, ripple filter, non linear load and three phase grid connected feeding . The proposed model improves the power factor, zero voltage regulation and eliminates the harmonics in the AC mains by using current controller and ripple filter. In current controller the reference grid currents sensed at PCC is used to control the three phase inverter. The model consists of PV array which connected to the boost converter and the VSC connected by boost converter where the voltages are controlled by using PI controller in current controller. The grid connected PV system is modelled and simulated in the MATLAB using the simulink and sim power system toolboxes.

Keywords- PV array, DC-DC boost converter, MPPT, voltage source inverter (VSI), zero voltage regulator, power factor, current controller, ripple filter, point of common coupling (PCC), PI controller and non linear load.

1. Introduction

Now a day's whole world is suffering from crisis of energy resources. Due to less resources of conventional energy has compelled us to move towards non-conventional source of energy among which solar energy is best source of non conventional energy. PV technology is costly because of storage devices and poor efficiency which can be improved by grid connected mode and MPPT method. The MPPT is used to track maximum power[1-2]. In grid interfaced PV system photovoltaic panels and they are connected to the utility grid. Grid interfaced PV generating system consist of photovoltaic panels, MPPT, dc-dc boost converter, and inverter. In grid connected PV-systems, an inverter is used to convert electricity from direct current(DC) as produced by the PV array to alternating current AC that is connected to grid.

In grid interfaced PV system, a two stage SPV power generating system using proposed voltage source inverter (VSI) is to improve power quality in AC mains. In first stage by using MPPT algorithm is used to track maximum power from PV array. The dc voltage generated from PV array is very less this can be improved by using dc-dc boost converter and in second stage the dc link voltage is controlled by using PI controller during varying current in non linear load[5]. A PI controller in current controller can also help in the compensation of reactive power and harmonic reduction of connected load at PCC (point of common coupling).

2. Design of Proposed System

A. Design of solar PV array

The output power of PV array is given as

$$P = VI = n_p I_{ph} V\left[\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1\right]$$

Where I is the PV array output current, V is the PV array output voltage, n_s is the number of module in series, n_p is the number of module in parallel, A is the p-n junction ideality factor it ranges between (1-5), T is the cell temperature (K), K is the Boltzmann constant. Here the PV array is design for 40KW. According to the design considerations one PV module consists of 36 cells in series. Each cell has open circuit voltage of 0.54V and short circuit current of 1A. Thus one module has open circuit voltage of 19V (18-21V) and short circuit current of 1A. For 40KW PV array we require 474V maximum voltage and maximum current of 84.39A corresponding to peak power of 40KW, to achieve this voltage (474/19) and current (84.39/1) 24 solar modules are connected in series and 84 are connected in parallel respectively[5].

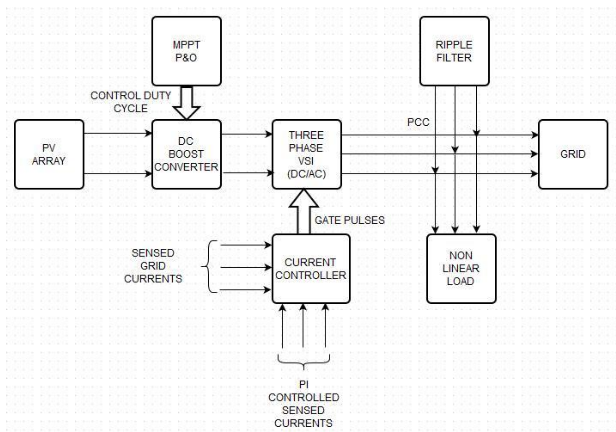

Fig.1 Block diagram of grid connected PV system

B. Design of boost converter

The dc-dc boost converter is used to boost the voltage by controlling the duty cycle (D). The maximum voltage is tracked by P&O control algorithm which is 474V and this voltage is boosted converter to 780V[3]. The Inductor and capacitor design value for boost converter is given as

$$L = \frac{V_{in}}{f_{sh}\Delta I} \ \ and\ C = R\left(\frac{D\Delta V_o}{f_{sh}V_o}\right)$$

Where D is the duty cycle. According IEC harmonics standard, the current ripple factor should be bounded to 10%. So input current I=84.39 then $\Delta I = 8.439A$, the voltage ripple factor should taken as 5% then $\Delta V_o = 39V$ and switching frequency of 10KHZ. The value of inductance obtained L=1.5mH and value of capacitor obtained C=800uf.

C. Selection of DC link voltage

Selection of DC link capacitor voltage is always two times greater than the peak of the phase voltage of the system as

$$V_{dc} = \frac{2\sqrt{2}V_{LL}}{\sqrt{3}}$$

Where m is the modulation index and it equal to 1 and V_{LL} is the ac line output voltage of VSI. Thus Vdc is obtained 780V for V_{LL} of 480V[6].

D. Selection of DC link capacitor

The value of DC link capacitor is given as

$$C_d = \frac{I_{dc}}{2wV_{dcripple}}$$

Where i_{dc} is the dc link current (dc link power/dc link voltage), w is angular frequency and dc ripple voltage is 5% of dc link voltage. The calculated value of dc link capacitor is 2000uF.

E. Design of AC inductor

The selection of the AC inductor is given as

$$L_f = \frac{\sqrt{3}m\,V_{dc}}{12hf_s\Delta I}$$

Where m is the modulation index is 1 and h is the overload factor is 1.2. $\Delta I = 5\%, f_s = 10khz, V_{dc} = 780V$ Considering current ripple The calculated value of ac inductor is 2mH.

F. Design of ripple filter

The design of shunt passive filter is used to tuned harmonic component in source current using LC filter. Here we used three phase filter but we consider single tuned filter, resonance frequency is given by

$$f = \frac{1}{2\pi\sqrt{L_r C_r}}$$

To design the size of capacitor, first step to fixed reactive power compensation. Hence capacitance can be calculated by

$$X_c = \frac{V_{LL}^2}{KVAR}$$

Where V_{LL} is the line to line source voltage. KVAR is fixed reactive power compensation[6].

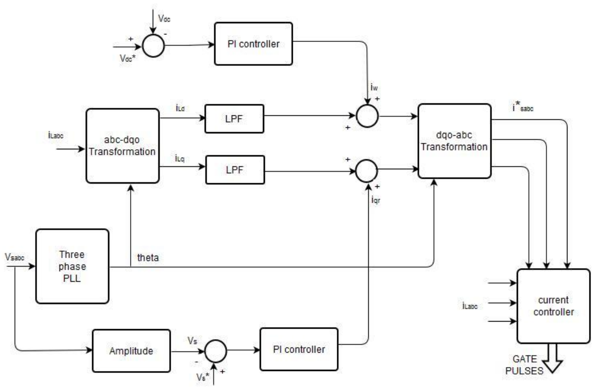

Fig.2 Block diagram of current controller technique for three phase VSI

3. Current Controller Technique To Control Power Factor & Voltage Regulation

A. Control of three phase VSC

The control approach used for estimation of reference AC mains currents for the control of VSC is a synchronous reference frame theory. The transformation of the load currents in synchronously to rotating d-q frame. This control is shown in figure.2 load currents(i_{labc}), point of common coupling voltage (V_{abc}) and DC bus voltage (V_{dc}) of VSC are sensed as feedback signals. Load currents from abc to dqo is converted by using abc-dq transformation block matlab simulink[1-2].

Where θ is obtained using a three phase locked loop (PLL) over PCC voltage (V_{abc}). Harmonics are filtered from reference signals by using low pass filter (LPF). The d axis and q axis current consists of DC and non DC harmonic quantities are separated by LPF. Now only DC quantities are in the reference signals.

$$i_{Ld} = i_{d\,dc} + i_{d\,ac}$$

$$i_{Lq} = i_{q\,dc} + i_{q\,ac}$$

B. Control for improvement of power factor

For improvement of power factor using reactive power compensation, the current controller consider that AC mains must delivers d-axis component of load currents along with current for regulating DC bus voltage constant and for feeding the VSC losses (i_w). The DC bus PI controller require to regulate DC link voltage and for compensation of VSC losses[5]. The current component to meet losses is given as

$$i_w(k) = i_w(k-1) + k_{pd}(v_{de}(k) - V_{de}(k-1)) + k_{id}(V_{de}(k))$$

Where sampling $V_{de}(k) = V_{dc}^*(k) - V_{dc}(k)$ at k^{th} sampling, V_{dc}^* is the reference voltage of sensed, V_{dc} common DC bus at K sampling, k_{pd} and k_{id} are the gains of DC bus voltage PI controller.

The amplitude of reference AC main current is given by

$$i_d^* = i_{ddc} + i_w$$

C. Control for improvement of voltage regulation

The improvement of voltage regulation at PCC is done by proposed model consider that AC mains must deliver same d-axis component along (i_d^*) with q-axis current (i_{qabc}) and PI voltage controller output (i_{qr}) to regulate the voltage at PCC. The voltage error from amplitude terminal voltage is (V_s^*) and its reference (V_s) is regulated by using PI controller[5]. The amplitude of terminal voltage is calculated as

$$V_S = \sqrt{\frac{2}{3}}\sqrt{V_{sa}^2 + V_{sb}^2 + V_{sc}^2}$$

The voltage is regulated by the voltage error between (V_s) and (V_s^*) by using PI voltage controller.

$$i_{qr}(k) = i_{qr}(k-1) + k_{pq}(V_{te}(k) - V_{te}(k-1)) + k_{iq}(V_{te}(k))$$

Where sampling, $V_{te}(k) = V_s^*(k) - V_s(k)$at k^{th}sampling, V_s^* is the reference voltage of sensed, V_s common DC bus at K sampling , k_{pq} and k_{iq} are the gains of DC bus voltage PI controller.

The amplitude of reference quadrature currents is given as

$$i_q^* = i_{qdc} + i_{qr}$$

The reference AC mains currents (i_{sabc}^*) are come from dq-abc transformation (i_{dqo}^*). These reference grid currents (i_{sabc}^*) are compared with the sensed grid currents (i_{sabc}) in the PWM current controller. After amplification of the current errors the output current amplifiers are given to discrete PWM GENERATOR of switching frequency 10KHZ to generate gating signals for IGBTs of VSC.

4. Result Analysis

In grid connected PV systems the THD value is less than 5% it means the proposed system is more reliable. The proposed grid connected system results shown in matlab simulink is shown below. In figure.3 shows the V-I characteristics of PV array and figure.4 shows the P-V characteristics of PV array is shown.

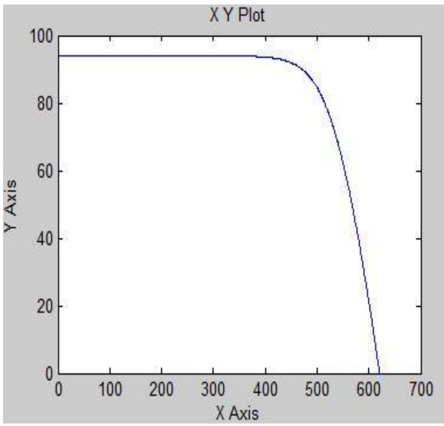

Figure.3 V-I characteristics of PV array

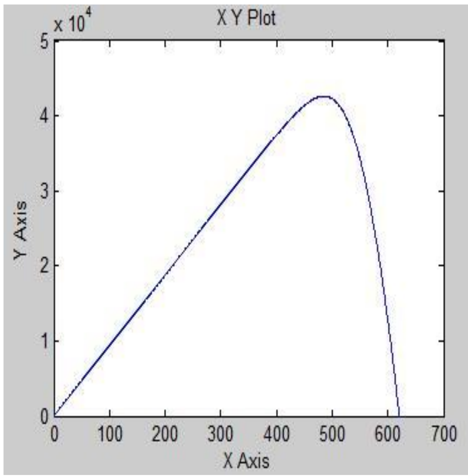

Figure.4 P-V characteristics of PV array

In figure.5 shows the pulses are generated from P&O algorithm according to solar radiation 1KW/m2.

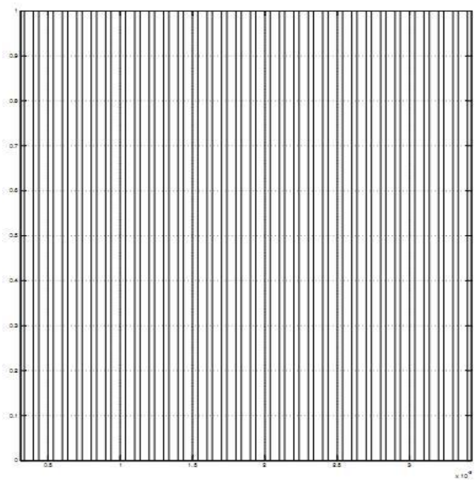

Fig.5 gate pulses are generated from P&O algorithm

In figure.6 shows the dc link output voltage are generated from boost converter having duty cycle of 0.397.

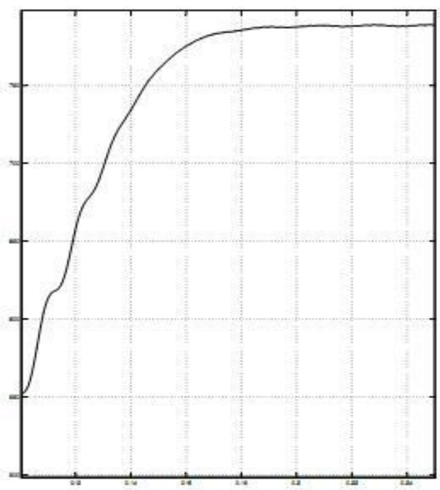

Fig.5 DC-link output voltage of boost converter

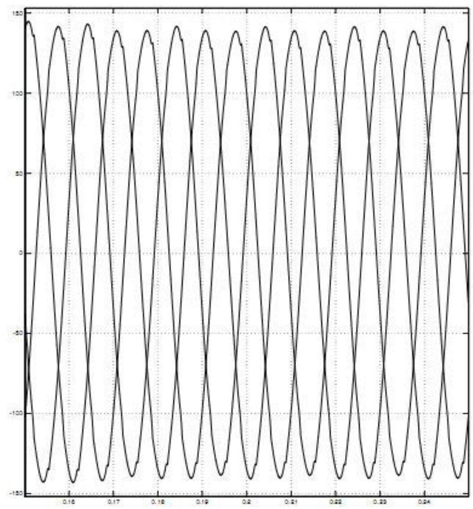

Figure.6 output three phase current at PCC

In figure.7 shows the output voltage of three phase inverter is 480V and input to the three phase inverter is 780V.

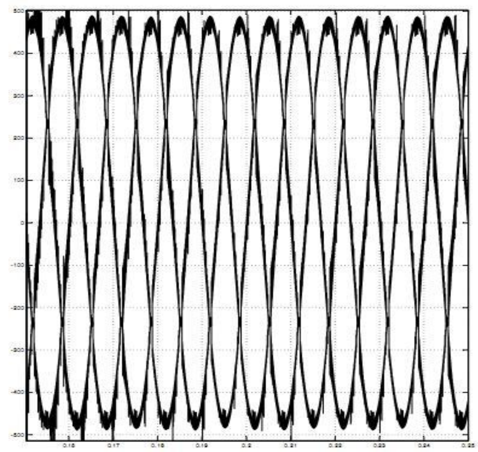

Fig.7 output three phase voltage of 480V at PCC

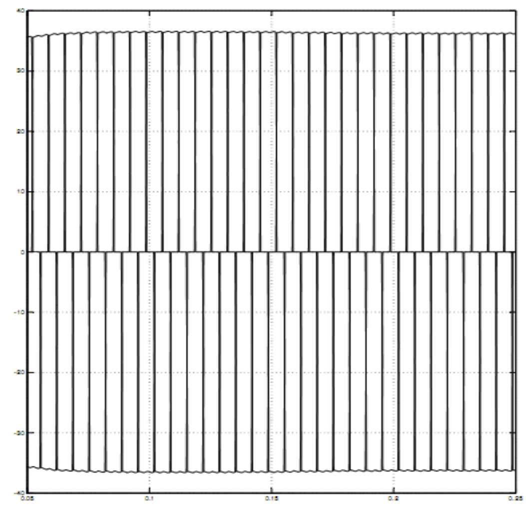

Fig.8 output load current at three phase non linear bridge rectifier

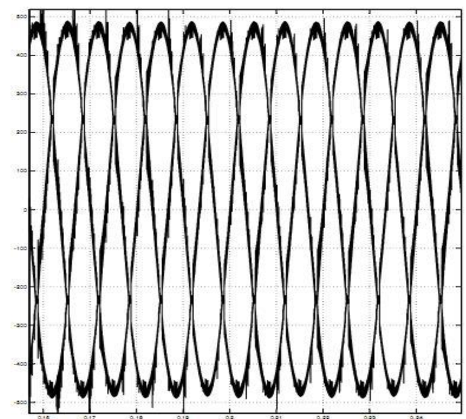

Fig.9 output load voltage at three phase bridge rectifier

5. Conclusion

The Current controller on grid connected system which improves the power quality like power factor, voltage regulation and decreases harmonics. In this project has been observe from the simulation results that to maintain constant DC voltage at output of Boost converter by Using MPPT technique and We maintain constant AC voltages by adding extra reactive power by proper tuning of PI controller and then controlling Voltage source converter(VSC). The three-phase VSC compensates the harmonic currents and reactive power, balances the nonlinear loads.

6. References

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Authors Details

Mr. S.Rajendra prasad received the B.Tech Degree in Electrical & Electronics Engineering from GMRIT, Rajam, Srikakulam ,India in 2012. Currently persuing M. Tech in Aditya Institute of Technology & Management, Tekkali, Srikakulam, India. His research interests include power quality, power systems, Power electronics and Drives.

Dr. K. B. Madhu sahu received the B. E. Degree in Electrical Engineering from college of Engineering. Gandhi Institute of Technology & Management, Visakhapatnam, India in 1985 and the M. E Degree in power systems from college of Engineering,Andhra University and Visakhapatnam in 1998. He obtained his Ph. D from Jawaharlal Nehru Technological University. Hyderabad. He has 27 years of Experience. Currently he is working as a professor & Principal in the Department of Electrical & Electronics Engineering, AITAM, Tekkali, and Srikakulam. Dt. Andhra Pradesh. His research interests include gas insulated substations, high voltage engineering and power systems. He has published research papers in national and conferences.

Sri.CH.KrishnaRao obtained B.Tech Degree in Electrical and Electronics Engineering from College of Engineering, GMRIT Rajam and Srikakulam Dt. He also obtained M.Tech in Power Electronics and Electric Drives from ASTIET Garividi, Vizayanagaram. He has 13 Years of Teaching Experience. Presently he is working as associate professor in the Department of Electrical & Electronics Engineering, A.I.T.A.M, Tekkali, and Srikakulam Dt Andhra Pradesh. He has published number of papers in journals, national and international conferences. His main areas of interest are power electronics, switched mode power supplies, electrical drives and renewable energy sources.