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Energy Procedia 117 (2017) 104–111

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Voltage Profile Improvement of Solar PV Grid – Connected Inverter with Micro Grid Operation using PI Controller

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Abstract

Microgrids (MGs) are initiating the large number of opportunities for the future of distribution units. Distributed generation resources (DERs) such as solar, wind, combined heat and power, energy storage, etc are tie up with the microgrid or distribution grid (DG) which can be used for improving the power quality. Distributed generation and microgrid are the most challenges to the power system network. This includes the stability, reliability, increasing power demand and power quality issues in power system. The objective of this paper is to improve the voltage profile of grid – connected PV systems. In the distribution system, PV source is the challenging one which is directly disturbs the power quality issues. Here MPPT algorithm is used to achieve the maximum amount of power in grid – connected PV systems. This paper presents the grid connected inverter with a PI controller is proposed. At the connection of point of common coupling real and reactive power by abc to dqo transformation could be compensated under the unbalanced load condition. The proposed control method is used to improve the voltage profile in the PV systems, dc voltage regulation across the grid side inverter control and to reduce the distortions under the sudden load changes. The effectiveness of the proposed system is replicated through the MATLAB/SIMULINK using Simpower system library.

Keywords: Micro – grid; Distributed generation; PV; MPPT algorithm; PI controller

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1876-6102
10.1016/j.egypro.2017.05.112

1. Introduction

Today, a large number of markets renewable energy is the cost effective one with fossil fuels and constructed as all over the world as conventional energy sources like solar, wind, biomass, geothermal, hydro, and thermal, etc. The generating capacity of solar PV and wind power saw its increase ever. Fig. 1 shows that the year 2015 data's in generating capacity of solar PV power in top 10 countries [1]. In recent years microgrid (MG) is one of the most interesting area in the electrical power system network. Generation, energy storage systems (ESS) and demand for green energy into MG could play a basic role in enlarging the quality and reliability of the power system. IEEE Std 1547.4-2011 states that MG can be operated as a flexible operation of both grid- connected and islanded mode [2,3]. It can be generating the electrical power from both conventional and non-conventional renewable energy sources. In grid- connected mode, each and every DG units regulates active and reactive power with the help of voltage and frequency of microgrid should be connected to the main utility grid, if the static switch is switched on. Also, this mode of operation each DG unit could be control by its real and reactive power [4]. The interfacing of a MG to the main grid system is a vital area to investigate the power quality problems which affects the utility grid voltages are unbalance load, high reactive power, harmonics and voltage sags, on the universal performance of the power system network. In the recent years, modification methodology are expanded in power quality because of the power system networks voltage quality problems are not a new concept [5,6].

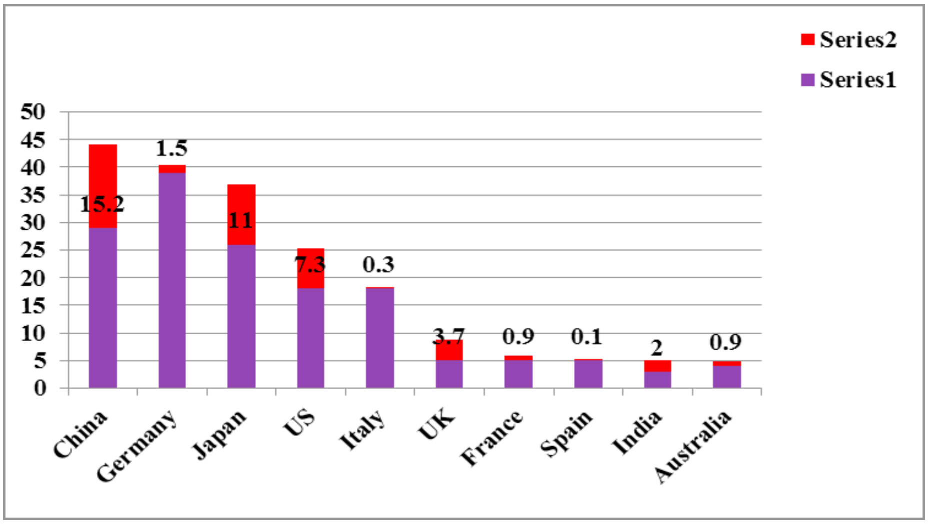


Fig. 1. Solar PV power capacity, top 10 countries in 2015.

Recent advances in micro grid have prompted numerous stability concepts much more by converters and inverters and decreased the instability of the powers. Usage of controllers will trace the current components in the control loop of the DG units in order to direct the frequency and voltage of the DG units [7]. Combination of controller design and optimization technique methods is effective for declining the disturbance in the presence of voltage and frequency and also droop controllers can conceive the coordination of multiple DG in a micro grid system which finds the amount of power sharing so that the micro grid can be stable in its voltage and frequency [8]. Interfaced inverter distributed generators can exploits in power system to mitigate the instability of voltage and frequency and to improve the stability of powers. With the various recent advancements of new controller methodologies, the proviso of their categorizations taking into account of effective stabilization have gotten to be vital [9].

Solar PV systems with grid connected inverter have less maintenance and cost effective comparing to the other micro grid system. The range between 100 watts single PV to more than 290 megawatts PV module is generated by the grid connected PV system [10]. This paper presents the improvement of voltage profile in solar PV using PI controller. The solar MPPT is connected to the grid side inverter through dc-dc converter with three phase load. The proposed PI controller technique is used to tuning the parameters based on the pre specified operating points including the abc to dqo transformation [11]. The simulation results of the solar PV grid connected micro grid system using PI controller are to improve the voltage profile of converter side and load side in the PV module.

1.1. System description

The overall system consists of a solar PV system than can be generates the output power by increasing the maximum power point tracking of the PV panel. This PV panel is connected to the PI controller through the dc-dc converter [12-14].

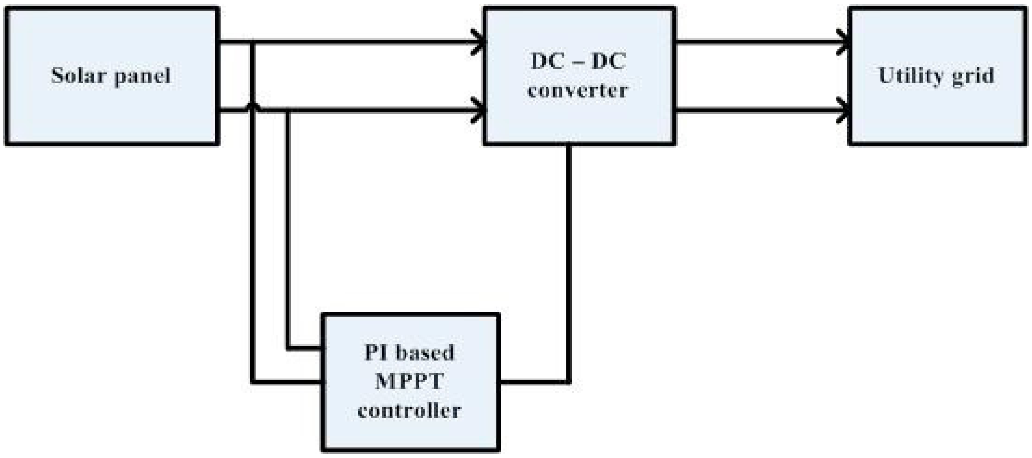


Fig. 2. Overall solar PV panel configuration.

1.2. Modelling of solar MPPT

The equivalent circuit of solar panel is shown in Fig.3 [15], and the mathematical modeling of solar PV is given by,

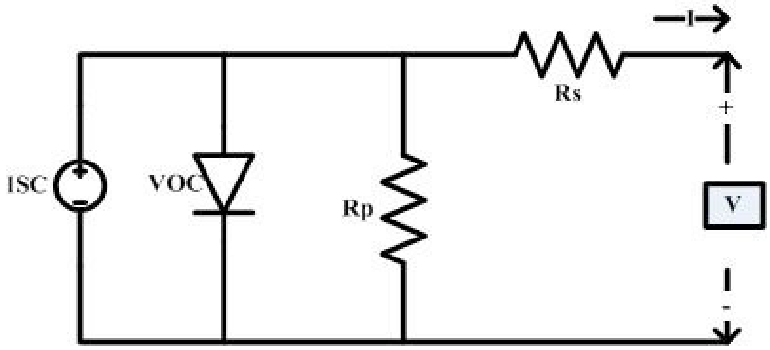


Fig. 3. Equivalent circuit of solar PV panel.

The mathematical equations are,

$$I = I_{PV} = I_0\left(e^{\frac{V+IR_s}{aV_t}} - 1\right) + \frac{V + IR_s}{R_p} \quad (1)$$

$$I_{PV} = I_{SC} = m_p\left(I_{SCN} + k_i\Delta T\right)\frac{G}{G_N} \quad (2)$$

$$I_0 = \frac{I_{SC}}{e^{\frac{V_{oc}}{aV_t}} - 1} \quad (3)$$

Therefore,

$$V_{oc} = m_s\left(V_{ocN} + k_v\Delta T\right) \quad (4)$$

Where,
I_{PV} - Photovoltaic current
I_{sc} - Short circuit current
K_i, K_v – Co-efficients of short circuit current with respect to operating temperature
G & G_N – Irradiance and nominal specified irradiance of the panel
T – Operating temperature

The given equivalent circuit model is implemented in MATLAB Simulink using components such as diode, resistance R_p and R_s, current source are applicable in Simpowersystems library.

1.3. Proposed PI controller

In our control structure, voltage controller using the PI controller to eliminate the voltage error and find the optimal solutions produces the current signal. Simple P-I controller having K_p and K_i as proportional and integral gain is used for tuning the PI controller. The basic PI controller block diagram given by Fig.4.

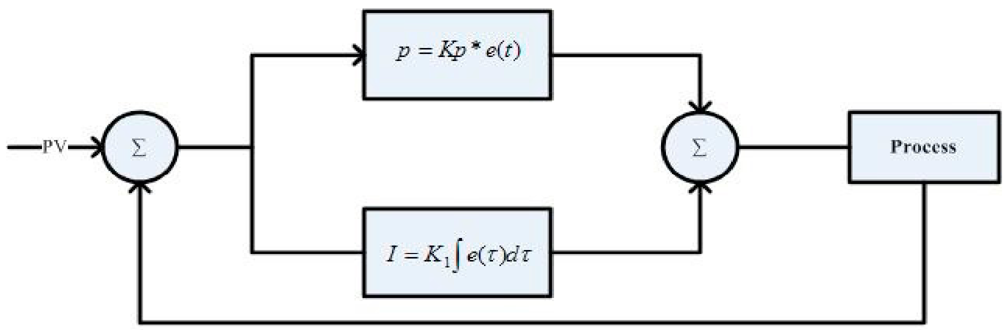


Fig. 4. Block diagram of PI controller.

PI controller is an integral error compensation scheme; the output response depends in some manner upon the integral of the actuating signal. This type of compensation is introduced by using a controller, which produces an output signal consisting of two terms, one proportional to the actuating signal and the other proportional to its integral [16]. Such a controller is called proportional plus integral controller or PI controller. In this paper, synchronously rotating abc to dqo reference frame using PI controller is implemented in PV inverters. The major function of this controller is eliminating the disturbances are insensitive to the power system variations. In [17], the design of PI controller real and reactive power components of abc to dqo transformation is given by equation 5 and 6.

$$P_2 = (3/2)\left(V_{2d}I_{id} + V_{2q}I_{iq}\right) \tag{5}$$

$$Q_2 = (3/2)\left(V_{2q}I_{id} - V_{2d}I_{iq}\right) \tag{6}$$

Where,
P_2, Q_2 are the instantaneous real and reactive power.
V_{2d}, V_{2q} are the PCC voltage.
I_{2d}, I_{2q} are the PCC current.

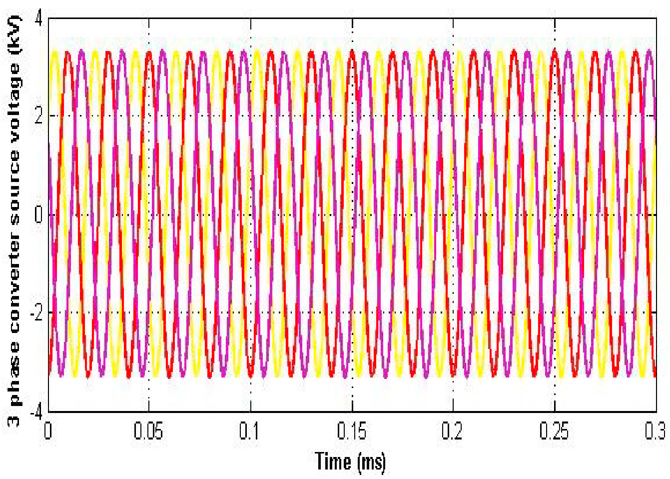
2. Results and discussions

The proposed 1kW, 50Hz PV system on the low voltage distributed system is integrated to the microgrid is simulated under the MATLAB Simulink. The proposed controller shows the effectiveness of the poor dynamic response of the PV system and improves the voltage profile. Here DC power source is directly connected to the utility grid, hence reactive power could be negligible in the PV inverter system. The overall parameter of PV grid connected inverter used in the Simulink is mentioned in Table 1.

Table 1.Parameters of grid – connected PV system consideration.

Parameters	Values
PV panel	1 kW
Grid voltage	440 V
Frequency	50 Hz
Switching frequency	5 kHz
Capacitance	2e-3
Resistance	1e-3

In Fig.5 a and b shows the three phase source voltage of PV converter and current converter. It describes the output of the phase A, phase B, phase C voltage is 300 V.



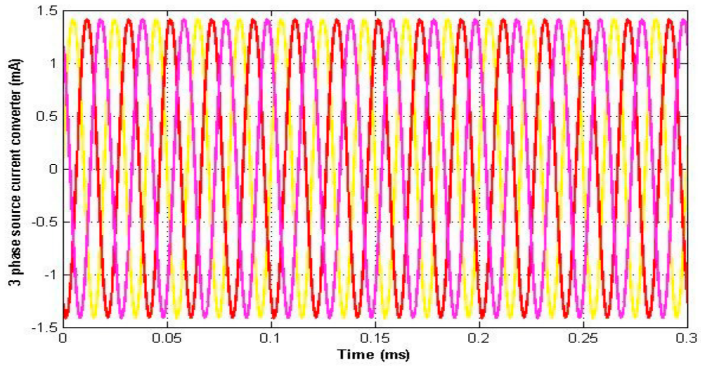


Fig. 5. (a) Source voltage of PV converter; (b) Source current of PV converter

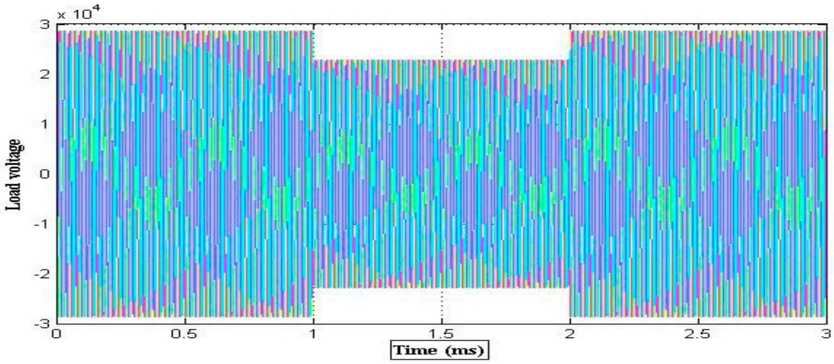


Fig. 6. Grid – connected load voltage

In Fig.7 observed that the PV and utility grid provides reliability of reactive power to the load. The proposed controller performs the accuracy of the interconnection of utility grid. The power factor is maintains at 0.9. Fig.8 shows that the duty cycle and DC current of the solar PV system.

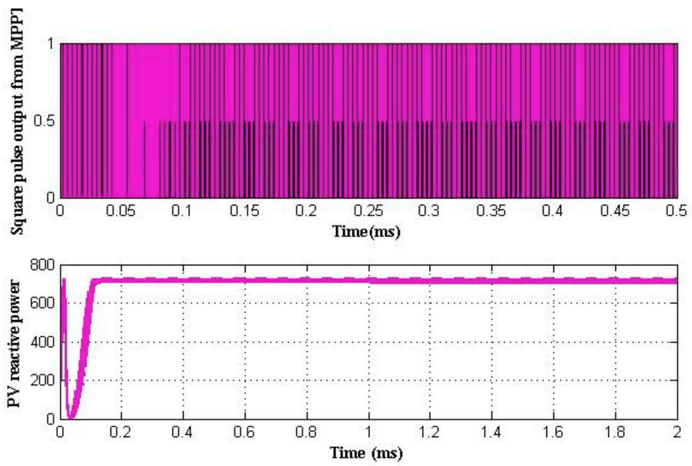


Fig. 7. PV reactive power

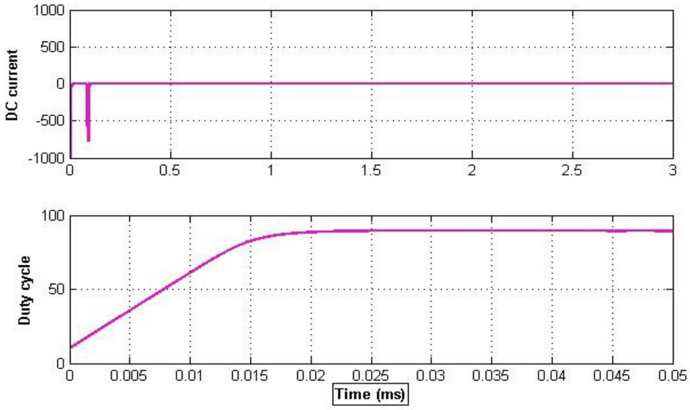


Fig. 8. DC current and duty cycle

3. Conclusion

In this paper, solar PV Grid – Connected Inverter with micro grid operation using PI controller is presented. The whole system performance is developed and simulated by using MATLAB/SIMULINK environment. The control strategy of PI controller in the grid connected solar PV system gives effective results compared to the PID controller in terms of output of the inverter current control and overall system response. The simulation of the grid connected PV systems improves the voltage profile of converter and load side was evaluated.

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