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DESIGN OF GRID CONNECTED SINGLE PHASE ROOFTOP PV SYSTEM USING P&O MPPT ALGORITHM

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Abstract— This paper presents a modular photovoltaic (PV) inverter for single phase grid-connected applications this inverter helps to improve the low THD sinusoidal line compensating currents and to improve the reactive power Compensation. The roof top PV system is connected to grid and works with a battery back for off grids system to realize better utilization of PV modules and maximize the solar energy extraction, and PV power is being tracked with An incremental conductance maximum power point tracking. Synchronous reference Frame theory based PWM is used for Controlling of Inverter. PI controller is used controller of DC link voltage. This system is implemented using Matlab/simulink software and results show the effectiveness of the system.
Keywords— PV system, SRF theory, PI controller, Power quality, DC-DC converter.

1. INTRODUCTION

Due to the shortage of fossil fuels and environmental problems caused by conventional power generation, renewable energy, particularly solar energy, has become very popular. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years [1], and the growth is mostly in grid-connected applications. Single phase rooftop PV systems are major research area for grid integration, since these sources have huge opportunity of generation near load terminal [2]. In a grid-connected PV system, control objectives are met by a strategy using a pulse width modulation (PWM) scheme based on two cascaded control loops [3]. The two cascaded control loops consist of an outer voltage control loop to settle the PV array at the MPP, and an inner current control loop to establish the duty ratio for the generation of a sinusoidal output current, which is in phase with the grid voltage [4]. The current loop is also responsible for power quality issues and current protection for which harmonic compensations and dynamics are the important properties of the current controller. Linear controllers such as proportional-integral (PI), hysteresis, and model predictive controllers are presented in [5]–[8], which provide satisfactory operation over a fixed set of operating points as the system is linearized at an equilibrium point. Since the PV source exhibits a strongly nonlinear electrical behaviour due to the variation of solar irradiance and nonlinear switching functions of inverters. As linear controllers for nonlinear PV systems affects all the variables in the system and the electrical characteristics of the PV source are time varying, the system is not linearizable around a unique operating point or trajectory to achieve a good performance over a wide variation in atmospheric conditions. With PV sources connected at the DC side of the inverter, it is utmost essential to fetch maximum power from the source to make the system efficient. Out of different algorithm to track maximum power point (MPP) such as perturb and observe (P&O), Incremental Conductance (IC) etc., IC based method provides fast dynamics and control over fast changing insulation condition [6] [8]. In this paper a new SRF theory has been proposed for single phase roof top inverter. The inverter controller is based on the current driven PWM based voltage controller which is capable of both current and voltage controller. PI controller is used for maintaining DC link voltage and by maintains DC voltage constant during operations, is ensured the total power being generated by PV across the dc bus by the inverter by the grid. And in order to boost up the dc Voltage DC-DC boost converter is connected between PV system and Inverter The Rooftop PV inverter is modelled using MATLAB/SIMULINK software and results sows the effectiveness of the system.

2. SYSTEM CONFIGURATION

Figure 1 shows the Schematic of the implementing system. It consists of Single phase Grid and Load. PV panel and this panel is connected to the DC-DC converter and there is a Capacitor placed after the Dc-dc converter which acts as a Dc link Voltage Source. The Single phase is connected in between the Single phase and Load at the point of PCC (Point of Common Coupling) with the help of the Injection transformer. Incremental Conductance based MPPT is used and its output is feed to DC-DC converter in order to Dc link constant. The direct voltage controlled current driven by Voltage Source Converter keeps the voltage constant across the tank capacitor by regulating the power evacuation via voltage control. The harmonics at the PCC can be filtered out by the proper design of LCL filter at the output of VSC. The conventional 3 phase SRF theory is modified to suit the single phase system. The modified SRF theory is applied to decompose the load current to generate the reference reactive power current command. Reference for the real current component is obtained by applying PI controller on the error between measured voltage and the reference voltage.

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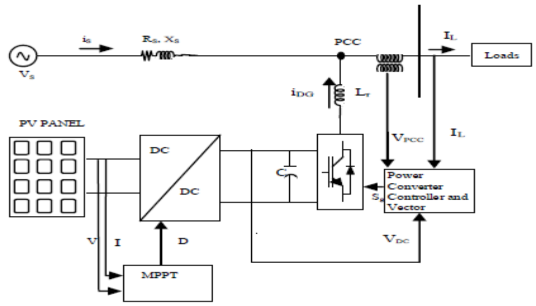

Figure 1

3. MODELLING OF PV

PV array is a p-n junction semiconductor, used to convert sunlight into electrical energy. When the incoming solar energy exceeds the band-gap energy of the module, photons are absorbed by materials to produce electricity. The cells in the PV array are tied in series or parallel and the electrical power of the PV array depends upon the solar irradiance, panel temperature and the operating current and voltage relationship. The current voltage relationship, which is the I-V characteristic of the PV array is a complex and non-linear function. The following exponential model is used to describe and predict the behaviour of our proposed photovoltaic module. According to this model, maximum power, Pmax equals (1)

$$P_{\max} = \frac{V_{op} * I_{sc}}{1-\exp\left(-1/b\right)} * \left[1-\exp\left(\frac{V_{op}}{b.V_{oc}} - \frac{1}{b}\right)\right] \tag{1}$$

$$b \cong \frac{\left(\frac{V_{op}}{V_{oc}} - 1\right)}{\ln\left[1 - \frac{P_{\max}}{V_{op} * I_{sc}}\right]} \tag{2}$$

$$R_{op} = \frac{V_{op} - V_{op} * \exp\left(\frac{-1}{b}\right)}{I_{sc} - I_{sc} * \exp\left(\frac{V}{b.V_{oc}} - \frac{1}{b}\right)} \tag{3}$$

Where ISC is the short circuit current, VOC is the open circuit voltage, IOP is the optimal current and IOP is the optimal voltage. Solving equation (1) for b and taking into account that b is very small; b can be estimated by equation (2). This value is distinct and unique for every solar panel and does not fluctuate with changes in irradiance and solar cell temperature. Thus for a particular irradiance level and cell temperature, if ISC, VOC, IOP and VOP are found for a given solar panel, the value of b can be achieved. By using the value of b in the exponential model, an accurate representation of the voltage and current characteristics of the panel can be obtained. Using the value of b, the optimal resistance Rop can also be found, which is the load resistance at which the photovoltaic panel transfers Pmax to the load.

3.1 Maximum Power Point Tracking (MPPT)

Maximum Power Point Tracking (MPPT) is very important in solar power system because it minimizes the solar array cost by decreasing the number of solar modules required to achieve the desired output power. MPPT is a device that looks for the maximum power point of a source and keeps it operating in that point. Since, the PV is not always operating in its maximum power point, but with the use of an MPPT it is possible to force the PV to extract the maximum power at the given irradiance level. We used P&O MPPT algorithm due to its simplicity and ease of implementation [2]. This technique is easily implemented by an algorithm using the power-voltage characteristics of the PV module. Knowing that at the right and the left of the maximum power point the power decrease, the converters duty cycle is changed depending on the last change in power and if the duty cycle was increased or decreased. To implement the P&O the power needs to be read at a time U, afterwards the voltage is changed. Next the power in time U+ I is read, if this power is incrementing we increment the duty ratio and by consequence the voltage in the PV. In the case that the power in the U+1 is lower than in the U time we decrement the duty ratio and by consequence the voltage. This technique operates in the boundaries of the MPP. The MPPT algorithm developed for this application is responsible for deploying the necessary adjustment in the Push-Pull Converter's duty cycle so that the optimum voltage is achieved, thus allowing maximum power delivery to the load [3]. The P&O, MPPT algorithm varying the push-pull converter duty cycle to obtain the maximum power delivered by Photo Voltaic panel is shown in figure 1.

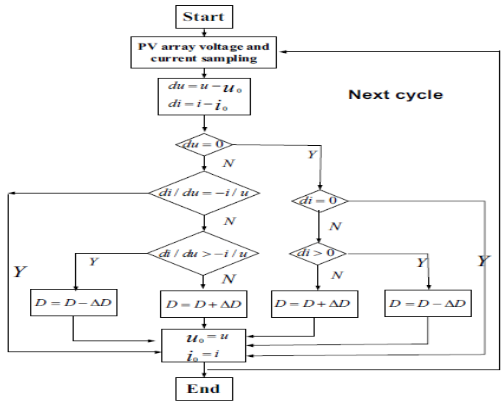

Figure 2

3.2 Control System

Figure 3 shows the control system of the proposed circuit. Here the Grid current is converted in to alpha beta components using Clark's transformation and same is done for load currents also. Here in order to find sin and cos components of for SRF method single phase discrete PLL is used. For the application of modified SRF theory to single phase system, phase voltage or current is taken as alpha (α) component in α-β frame (stationary frame of reference), and by introducing phase delay of 90° to alpha components, β component is obtained as shown in figure 3. The obtained are passed through low pass filter and the reference currents are obtained. Vdc from the capacitor and reference Vdc is obtained and both are compared using addition and fed to PI controller. Here pi controller is used to control the dc link voltage and the Error current is obtained and these currents are compared with the currents obtained from low pass filter and are fed to PI controller in order to get reference Error currents and then these are fed to PWM generator and PWM used here is sinusoidal pulse width modulation and these pulses are fed to VSI (Voltage source inverter).

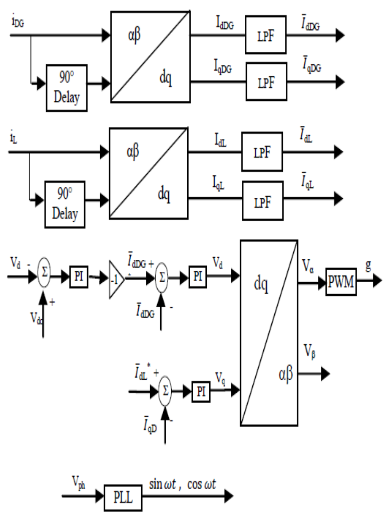

Figure 3

3.3 Matlab Simulation Implementation

The complete single phase grid connected PV system is simulated under MATLAB simulink with RL load (R= 4 Ω, L = 4 mH) as shown in Fig.4. PV panels are connected in series and parallel in such a way that array could deliver maximum power of 8.5 kW at 1000 W/m2 insolation level. IC based MPPT algorithm is verified by writing embedded MATLAB code. LCL filter is connected at the output of VSC as per parameters given in the table II. The simulated results are studied to compute the performance of single phase grid connected system under limited available capacity of VSC.

Table 1 Parameters of LCL Filter

L1	3mH
L2	3mH
L3	0.3mH
R1	0.02Ω
R2	0.02Ω
R3	0.02Ω
C	40µF
R	3Ω

Table 2 Parameters of Considered System

Vph	230 V
RL	5Ω
LL	4mH
DC link Voltage	400 V
Supply Frequency	50 Hz
Max. PV Power	8.5 kW

3.4 Performance Evaluation

Single phase grid connected photovoltaic based VSC with limited power conditioning is simulated under MATLAB simulink environment. The waveform of PCC voltage, source current, VSC current, load current, DC link voltage, MPPT power, and VSC output active and reactive power are shown in figure 5 (a) – (g) respectively. 0.4s onwards. With PCC point voltage maintained at 230 V total load demand which is 55.16 A is shared between two sources – the grid source and the PV source connected at PCC as shown in Fig. 5 (d). Assuming capacity of VSC 10.5 KVA, and available MPP power of 5.5 kW at 1000 W/m2 insolation, its capacity is shared between active and reactive power output of VSC. Till t=1s when the insolation is at 1000 W/m2, the MPPT extracted 5.5 kW power for transfer through VSC to maintain constant DC link voltage as shown in Fig. 5 (e). Till t=1s VSC and grid sources shared 21.6 A and 34.2 A respectively for total load demand as shown in Fig. 5 (b) - (c). During the same time VSC only supply a part of the total load reactive power demand (3.5 KVAr) which is 2.3 KVAr as shown in Fig. 5 (g). At t = 1s insolation level has changed to 500 W/m2 leading to decrease in PV power to 6.5 kW as shown in Fig. 5 (f).This decrease in active power supply through VSC results into additional room created for more reactive power compensation. As per the rating of VSC, full reactive compensation is provided through VSC amounting to 3.5 KVAr as shown in Fig. 5 (g). In turn source current from grid and VSC current gets redistributed after t = 1s to 26.5 A and 29.4 A respectively as shown in Fig. 5 (b)-(c). With the full reactive power compensation after t = 1s source voltage and current comes in phase resulting into unity power factor operation.

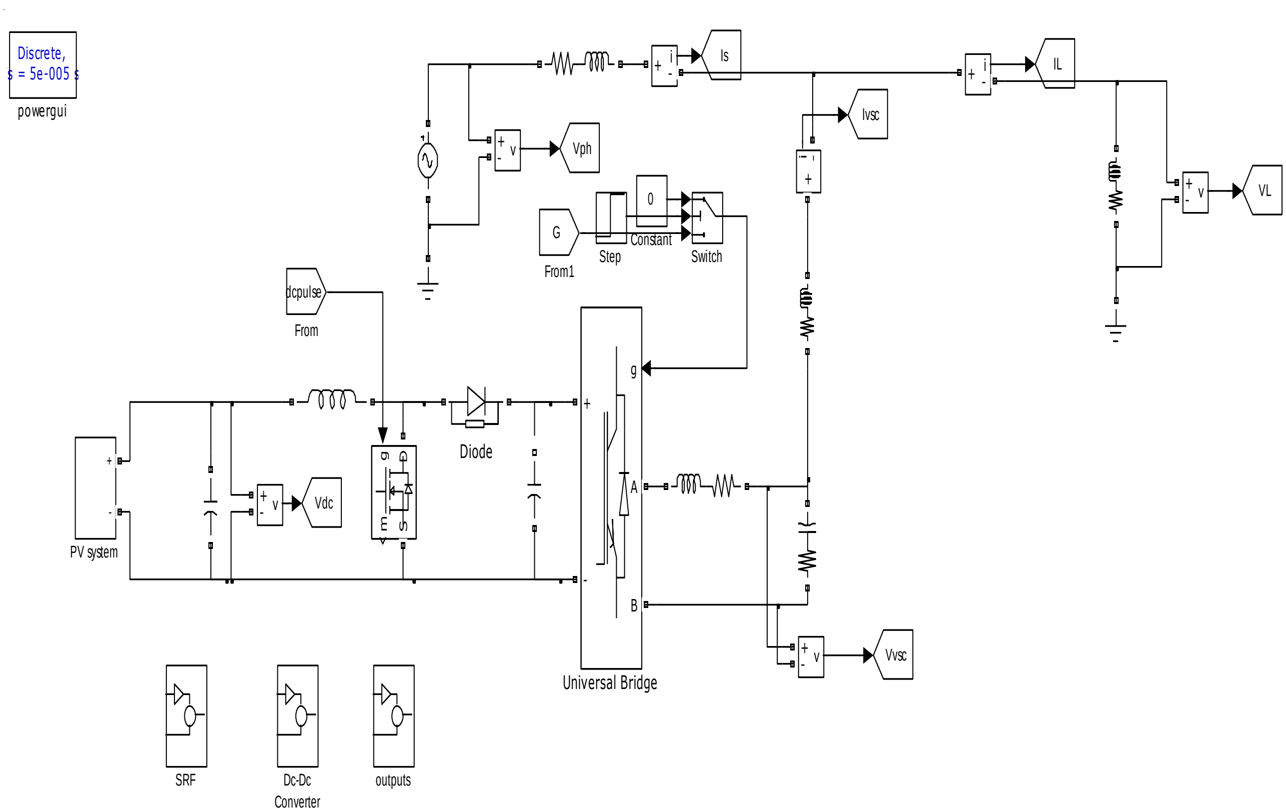

Figure 4

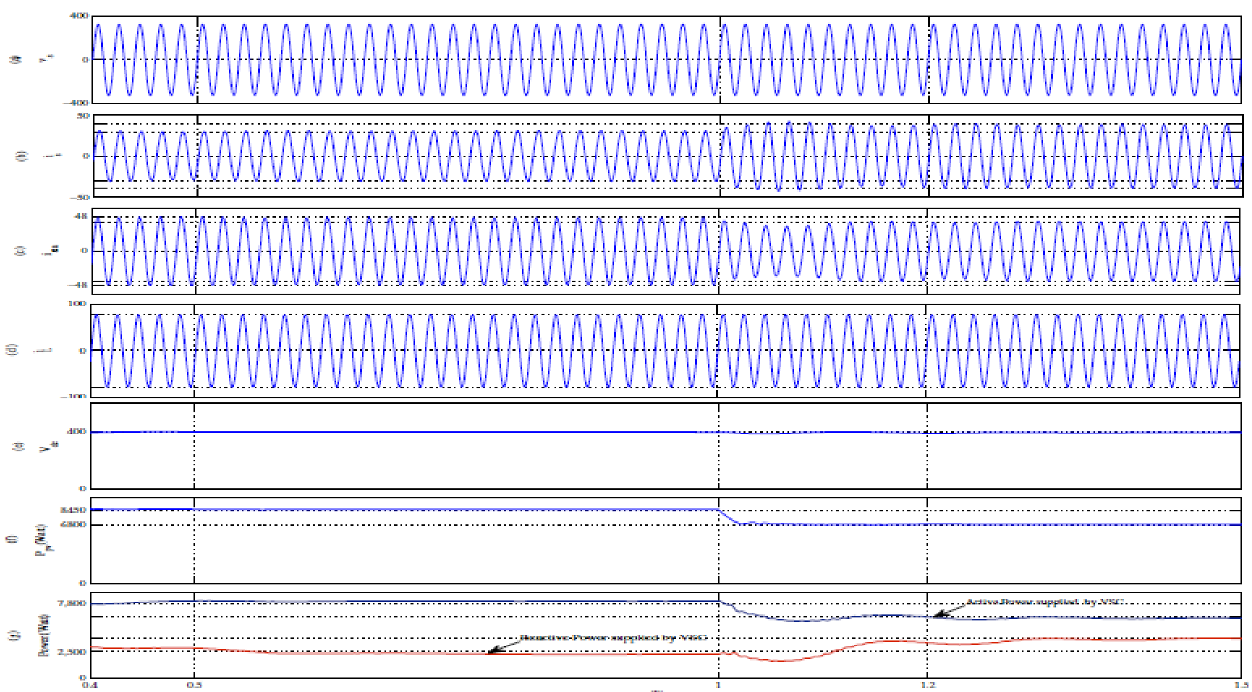

Figure 5

4. CONCLUSION

Through simulation we can see that the system completes the maximum power point tracking successfully despite of Fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly. Although there is little deviation in the results, the overall trends and forms are practical. In a word, all the designs have some practical significance on the development of the PV systems. The proposed approach enables the control for providing limited reactive power compensation depending on availability of unutilized capacity of VSC. The implemented scheme derives the advantage of simplicity and is capable of delivering under varying insolation conditions effectively. Result shows the effectiveness of the system and further paper can be implemented using Fuzzy logic controller.

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