International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Design & Simulation of Grid Connected PV Sourced NPC Inverter with Reactive Power Injection

Santhosh H V, Dr. Eranna

Abstract: ***In this paper, the proposed system consists of PV source supplying the grid using NPC inverter along with boost Converter. An MPPT algorithm is formulated to extract maximum power from the PV source and providing it to grid and load. A reactive power injection control is added with dc voltage control for the inverter so that if power generation is insufficient, reactive power is to be injected to provide more stability. The proposed systemis simulated in MATLAB/ Simulink software.***

Keywords: PV source, NPC Inverter, Boost converter, DC voltage control, Reactive power Injection

1. Introduction

Recently, the renewable energy sources are extensively used in distributed generation units. Mainly, the Photovoltaic (PV) energy is utilised by using the panels which is used in standalone applications as well as providing power to grid systems. In order t achieve this, devices such as dc - dc converters, dc - ac converters, filters transformers, etc are used. To achieve required performance several controllers are used like mppt control for dc - dc converters which extracts maximum power from the PV modules, inverter control for providing real and reactive power to the grid along with local loads connected to the DG units. The proper design of filters is also one of the requirements as it handles the power quality issues such as harmonics, power factor, voltage sag, swell, etc, to a certain extent. Different approaches are performed for the inverter control in PV based grid connected applications. The real and reactive power injection from PV inverter to grid is researched with α - β transformation instead of dq transformation and also various controllers such as PI, PID, fuzzy logic are used. The multi level inverter topologies are used instead of bridge inverters and although it have advantages, leakage current injection is a serious issue for PV inverters. It may cause higher thds, unbalance current flow if proper control is not adapted. Also the injected power from PV should be less than that of the inverter power capacity, so that the inverter is undamaged. It is seen in some of the previous works, the inverter only injects real power where as the THD and power factor is not controlled. Most of the control strategies left the harmonics and this leads to higher harmonic current and eventually leads to the damage of the inverter devices. Also, the switching losses are to be considered in the inverter design. Thus a inverter control strategy with low thd emission and better control in real power injection is needed. This paper proposes a PV power generation in which a boost converter is used for step up of voltage and NPC multi level inverter is used to fed power to grid and local loads. P&O based mppt algorithm is used for extracting maximum power from the PV source and an reactive power control loop is used for injecting the reactive power when the power generation from PV is reduced.

2. System Description

This proposed system as shown in Fig 1 consists of PV panel of voltage 60V and power capacity of 2KW. It is provided to boost converter in which the voltage is stepped up to 400V and provided to the inverter. The NPC multi level inverter provides the three phase output voltage of 200V. It is provided to step up transformer of 200V/11KV voltage ratio and connected to grid. Prior to that, local loads are connected to the system. The load is increased at t=0.2s and the controller is subjected to reactive power injection.

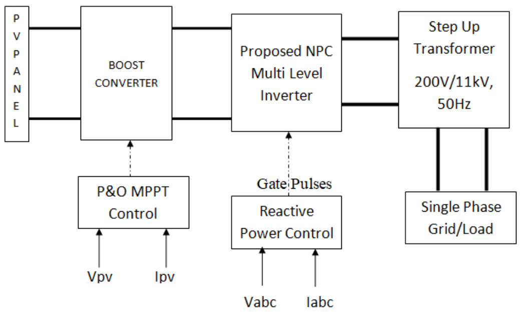

Figure 1 Proposed PV fed Grid connected NPC inverter

a) Photovoltaic Energy Conversion System (PVECS):
In this, the proposed system consists of the PV array which provides DC power according to the solar radiation. The PV power is shown in the following relation:

$$P_{PV} = W_{PV} f_{PV} \left[\frac{G_T}{G_{STC}} \right] \left[1 - \alpha_p (T_c - T_{C,STC}) \right]$$

where
W_{PV} - Nominal power of the PV array (kW), α_{p} - coefficient of temperature
f_{PV} - PV derating factor,
G_T - Actual irradiation (kW/m2),
G_{STC} - Rated irradiation (1 kW/m2 at 25),
Tc - Actual temperature of PV panel and $T_{C,\ STC}$ - standard temperature of the PV panel.

b) Boost Converter
The circuit for the boost converter is given in Fig.2 as follows:

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

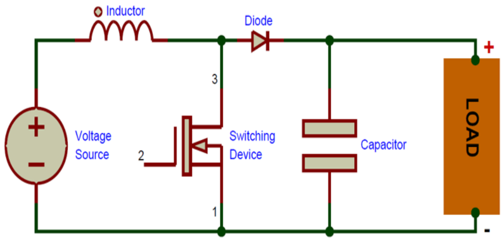

Figure 2: Boost Converter Circuit

The terminal voltage across the load is higher than that of source voltage with the help of inductor charging and discharging using the boost converter switch. It comprises of diode, inductor, power electronic switch (MOSFET) and capacitor. When the switch is turned ON, the inductor starts charging and the energy stored in the inductor increases and when the switch is turned OFF, the inductor starts discharging and combines with source voltage to provide boosted voltage to the load.

The duty ratio is given below as

$$D = \frac{Vo}{Vo - Vin}$$

The inductance is provided by the following relation:

$$L = \frac{Vin * D}{\Delta Io * Fsw}$$

The inductor ripple current is shown below:

$$\Delta I_L = 0.2 * \frac{Vo}{V_{in}} * I_o$$

The output capacitance is provided below:

$$Co = \frac{\Delta Ioc}{8 * Fsw * \Delta Vo}$$

The output ripple voltage is as follows:

$$\Delta Voc = 2\% \ of \ Vo$$

c) NPC Multi Level Inverter

The NPC inverter used in the proposed PV system is provided in Fig 3

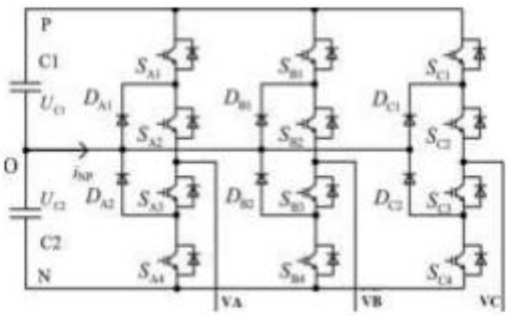

Figure 3: NPC Inverter

In this, the dc voltage is shared by the capacitors arranged in series. A group of power electronic switches and diodes is used to form each leg of the three phase inverter in order to get required voltage levels. Fig 1 provides the structure of three level NPC inverter. It comprised of two capacitors, four switches S_{A1}, S_{A2}, S_{A3} and S_{A4} and two diodes D_{A1} and D_{A2} for one leg. The switches S_{A1} and S_{A3} and S_{A2} and S_{A4} are complementary pairs respectively for phase A. Similarly S_{B1} and S_{B3} and S_{B2} and S_{B4} are complementary in phase B and S_{C1} and S_{C3} and S_{C2} and S_{C4} are complementary in phase C. The switching states for phase A is shown below in Table 1.

Table I: Switching Table for NPC Inverter

Symbol	Switching States				Terminal Voltage
	S_{A1}	S_{A2}	S_{A3}	S_{A4}	
P	ON	ON	OFF	OFF	E
O	OFF	ON	ON	OFF	0
N	OFF	OFF	ON	ON	-E

3. Control Strategy of Proposed System

a) MPPT Control

The Perturb and Observe algorithm based MPPT controller will provide the maximum power extraction from the PV source and provides to the load by generating the appropriate duty ratio and provided for pwm pulse generation unit. The pulse is given to the boost converter switch. The P&O mppt operates under the following conditions:

1) If $\Delta P/\Delta V > 0$, ΔD is +ve,
2) If $\Delta P/\Delta V < 0$, ΔD is –ve.

The flowchart of the P&O algorithm based mppt is provided below in Fig 4:

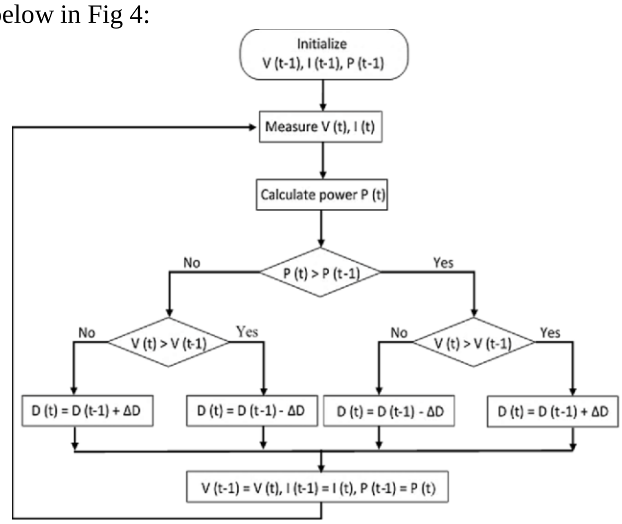

Figure 4: P&O Algorithm based MPPT control

b) Reactive Power Control

The harmonics can be removed by the following strategy as shown in Fig 5. It is based on the equations for balanced instantaneous power in three phase power system. Initially, the Clarke transformation is performed where the three phase coordinates are converted to α - β coordinates which is shown below:

$$[M] = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta_1(t) & \cos\theta_2(t) & \cos\theta_3(t) \\ \sin\theta_1(t) & \sin\theta_2(t) & \sin\theta_3(t) \end{bmatrix}$$

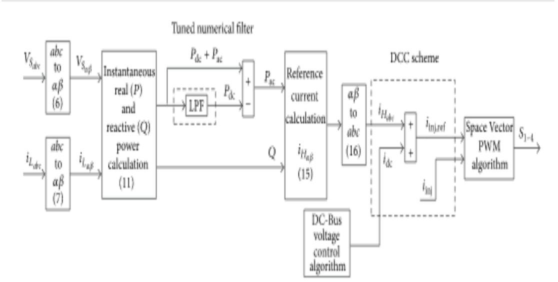

Figure 5: Controller block diagram

The three phase grid voltage and current subjected to Clarke - transformation is shown below:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

In α - β coordinates, the power is expressed as

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}.$$

The harmonics in the system is removed by introducing the harmonic currents in the system with phase opposite to the sensed harmonic currents. This is represented as follows:

$$P_{\text{ac}} = P - P_{\text{dc}}.$$

The harmonic free real and reactive power is provided below:

$$\begin{bmatrix} P_{\text{ac}} \\ Q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_{H_\alpha} \\ i_{H_\beta} \end{bmatrix}$$

Inverse Clarke - transformation is done so that the controlled current in α - β coordinates is converted to three - phase reference current which is shown below:

$$\begin{bmatrix} i_{H_a} \\ i_{H_b} \\ i_{H_c} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{H_\alpha} \\ i_{H_\beta} \end{bmatrix}.$$

This reference current is provided to hysteresis control which generates the pulses accordingly.

4. Simulation Results

The simulation circuit of the proposed system is provided below in Fig 6:

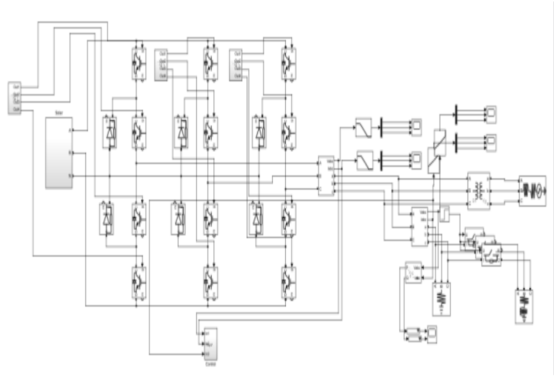

Figure 6: Proposed system

In this, PV energy is used for power generation with the PV voltage is 60V and power is 2KW and system voltage is around 400V. PV source is connected with dc - dc converter in order to get boosted voltage, so that it can be connected the load and grid. It is connected to inverter and then provided to load of 400V and 3KW.

The boost converter output voltage and current is provided in Fig 7.

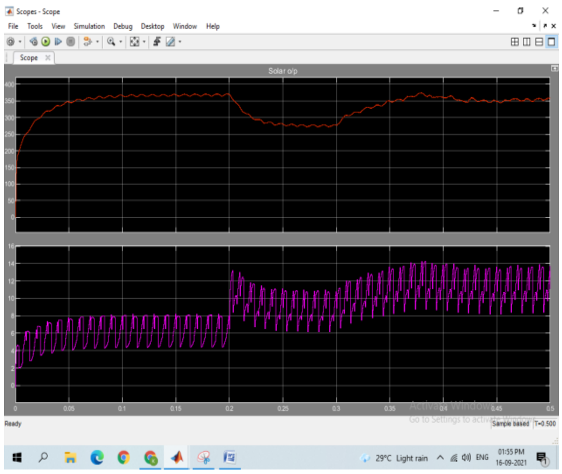

Figure 7: PV system output voltage and current

The duty ratio from the mppt is increased at t=0.2s from 0.7 to 0.9s. It is shown below in Fig 8:

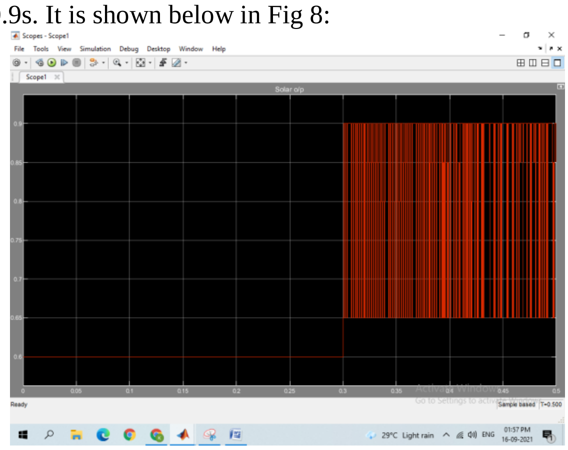

Figure 8: Duty ratio from mppt controller

In this, the voltage generated form boost converter is reduced from 340V to 300V and increased again due to the controller. The reduction in voltage is due to increase in the system load at t=0.2s. It is reflected on the load voltage and current waveforms as shown in Fig 9:

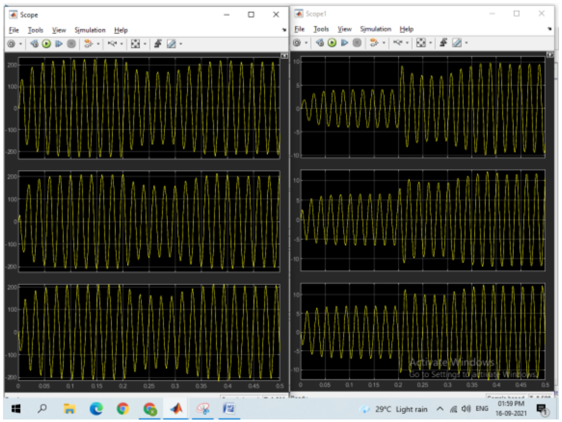

Figure 9: Load voltage and current

Similarly the load power also reduced due to increase in power demand and gets recovered. The real and reactive power is shown below in Fig 10:

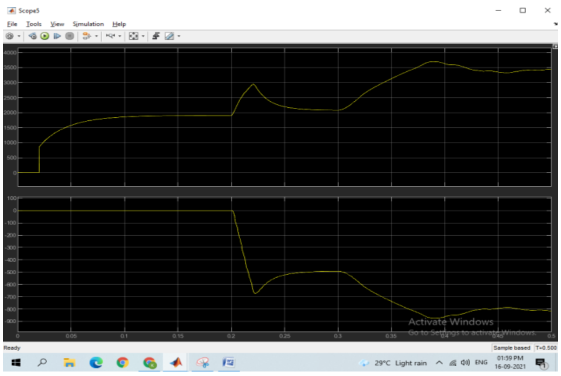

Figure 10: Real and Reactive Power

In this, the load is suddenly connected at t=0.2s and hence the reactive power is injected into the system. The %THD of the proposed system with filter is provided below in Fig 11:

Figure 11: %THD of load current with filter

The %THD of load current with filter is around 5.25%.

5. Conclusion

In this paper, PV energy conversion system is designed and simulated. The performance of the system is noted during steady state and transient conditions. The controller is designed for reactive power injection, when the PV power is less than that of load demand. MPPT controller is designed for extracting maximum power and reactive power control loop is also designed to inject the reactive power in the grid. It is used to regulate PCC voltage and the performance of the controller is noted.

References

[1] Y. Joka, H. Sasaki, “Protection coordination scheme for distribution networks with high penetration of photovoltaic generators, ” in IET Generation, Transmission & Distribution vol.12, April 2018, pp.1802–1814.

[2] M. Uma Maheshwara Rao, K. Mercy Rosalina, “Modeling of a Microgrid Connected Hybrid System using Solar, Wind and Fuel cell”, JourofAdv Research in Dynamical & Control Systems, vol.10, July 2018, pp.1908 - 1915.

[3] K. Walled, A. Najy, “Optimal Protection Coordination for MicrogridsWith Grid - Connected and Islanded Capability”, IEEE transactions on industrial electronics, vol.60, 2013, pp.1968 - 1977.

[4] D Q Hung, N. Mithulanandham, “Multiple distributed generators placement in primary distribution networks for loss reduction”, IEEETrans. Ind. Electron, vol.60 no.4, April 2018, pp.1700 - 1708.

[5] P. S. Shete, N. S. Maurya, R. M. Moharil and A. A. Dutta, “Analysisof Micro - grid under Different Loading Conditions, ” International Conf. on Industrial Instrumentation and Control, 2015, pp.1120 - 1124.

[6] Z. Kai - Hui and X. Ming - Chao, “Impacts of Microgrid on Protection of Distribution Networks and Protection Strategy of Microgrid, ” IEEEConf. on Advanced Power Sys. Automation and Protection, Vol.1, 2011, pp.356 - 359.

[7] R. Enio, Ribeiro and Ivo Barbi, “Harmonic Voltage Reduction Using a Series Active Filter Under Different Load Conditions”, IEEE Transactions on Power Electronics, vol.21, no.5, September 2006, pp - 1394 - 1402.

[8] Z. Kai - Hui and X. Ming - Chao, “Average Modeling and HybridControl of a Three - Phase Series Hybrid Power Filter,” IEEE International Symposium on Industrial Electronics, vol.2, July 2016, pp.919 - 924.

[9] M. Uma Maheshwara Rao, K. Mercy Rosalina, “Microgridprotectionby using resistive type superconducting fault current limiter,” Modelling, Measurement, and Control A, Vol.91, no.2, June2018, pp.89 - 93.

[10] P. Salmerón, S. P. Litrán, “Improvement of the Electric Power QualityUsing Series Active and Shunt Passive Filters”, IEEE Transactions on Power Delivery, vol.25, no.2, April 2010, pp - 1058 - 1067.