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A New Topology for Reactive Power Compensation in Grid Connected PV System

Naga Srinivas Nakka[1], Kuna Rajesh[2]

[1]Assistant Professor, Dept of EEE, Sri Sivani College of Engineering, Srikakulam.

[2]PG Student, Dept of EEE, Sri Sivani College of Engineering, Srikakulam.

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ABSTRACT

Grid tied solar inverters are designed to generate power at unity power factor which means that they have capability to produce active power only. The reactive power requirement of the load is catered by grid only. With the suddenly increase in the deployment of renewable based Distributed Energy Resources, reactive power drawn from the grid as compared to active power has increased considerably. This affects the power quality of the grid. If the grid tied solar inverter is made smart in terms of supplying reactive power in addition to active power and reactive power requirement from the grid will reduce as the grid has to supply lesser reactive power. To maintain proper synchronization between PV and grid system to suitable controller is designed for the inverter. For this purpose, this work proposes a svm controller for PV inverter to mitigate the system voltage fluctuations. Also, the method considers the loss associated with the reactive power production. Simulations are presented to assess the voltage regulation characteristics under different load conditions.

.**KEY WORDS:** *Photovoltaic System, P & O MPPT, Boost Converter, SVM controller and Grid Connection.*

INTRODUCTION

At present, most of energy demand in the world relies on fossil fuels such as petroleum, coal, and natural gas that are being exhausted very fast. One of the major severe problems of global warming is one of these fuels combustion products, carbon dioxide; these are resulting in great danger for life on our planet [1].

Among all the available Renewable energy sources, PV array systems are trusted to play a significant role in prospective energy production. PV systems transform photon energy into electrical energy. These energy systems generate low voltage output, thus, high step-up dc/dc converters are employed in many applications, including fuel cells, wind power, and photovoltaic systems, which converts low voltage into high voltage. Due to the increasing demand on electricity, and limited availability and high prices of non-renewable sources, the photovoltaic (PV) energy conversion system has becomes an alternative as it is freely available, pollution free, and has less operation al and low maintenance cost. Therefore, the utilization of PV energy systems has to be increased for standalone and as well as grid-connected modes of PV systems. Photovoltaic (PV) as a renewable energy resource naturally is not stable by location, time, season and weather and its installation cost is comparatively high. An important consideration in increasing the efficiency of PV systems is to operate the system near maximum power point (MPP) so to obtain the approximately maximum power of PV array. For getting maximum possible energy produced by a solar system.

Also maximum power point tracking (MPPT) techniques are used for improving the performance of PV systems, a high efficiency power converter which is designed to extract maximum power from a PV panel is usually considered. Generally, there will be a unique point on the V -I curve, called the Maximum Power Point (MPP), at which the whole PV system serves with maximum efficiency and produces its maximum power output [l5-17]. The position of the MPP is unknown, but can be placed either by search algorithms or through calculation models. Maximum Power Point Tracking Techniques (MPPT) are used to maintain the PV array's operating point at the precise position where maximum power can be delivered [26-28]. Various MPPT algorithms have been considered in the literature; some of them are the Perturb and Observe (P&O) method [2-5], the Incremental Conductance (lC) method [2-6], the Artificial Neural Network method [7], the Fuzzy Logic method [8] etc .. The P&O and IC techniques, are the most widely used. In this paper, four MPPT algorithms are considered: P&O, Incremental Conductance (lC) method [2-6], Fuzzy Logic method [8], Particle Swarm Optimization method [l0].These methods are quite easily implemented and have been widely adopted for low cost applications. Other methods such as Sliding Mode [9], are not considered in this paper, because they are more complex and rarely used.

This paper focuses on developing a simulation model to design and size the hybrid system for a variety of loading and meteorological conditions. This simulation model is performed using Matlab and SimPower Systems and results are presented to verify the effectiveness of the proposed system. The proposed grid connected hybrid energy generation system is shown in figure 1.

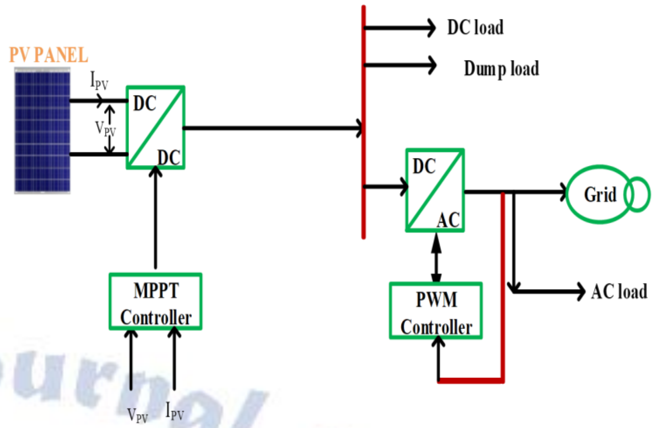

Figure 1: Configuration of proposed grid connected hybrid system

LITERATURE SURVEY:

Ciobotaru et al. discussed the issue of control strategies for single-stage photovoltaic (PV) inverter is addressed. Two different current controllers have been implemented and an experimental comparison between them has been made. A complete control structure for the single-phase PV system is also presented. Mahmud et al. presented a robust nonlinear distributed controller design for islanded operation of microgrids in order to maintain active and reactive power balance. In this paper, microgrids are considered as inverter-dominated networks integrated with renewable energy sources (RESs) and battery energy storage systems (BESSs), where solar photovoltaic generators act as RESs and plug-in hybrid electric vehicles as BESSs to supply power into the grid. Power electronics converters play an important role in realization and performance improvement of electrical power system. With the demand for new power resource and better power supply quality, more and more distributed energy resources (DERs) come into practice. A model predictive controller is designed to decrease common mode voltages and errors between the capacitor voltages and their reference values. Finally, simulation diagram, parameters and results using software PLECS are provided to demonstrate the merits of multilevel inverters and the validity of proposed control method by Bo and Yang.

SOLAR SYSTEM:

In photovoltaic (PV) system, solar cell is the basic component. PV array is nothing but solar cells are connected in series or parallel for gaining required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material [5]. It produces the currents when light absorbed at the junction, by the photovoltaic effect. Figure 3 shows at an insulation output power characteristic curves for the PV array. It can be seen that a maximum power point exists on each output power characteristic curve. The Figure 3 shows the (I-V) and (P-V) characteristics of the PV array at different solar intensities. The equivalent circuit of a solar cell is the current source in parallel with a diode of a forward bias. Load is connected at the output terminals. The current equation of the solar cell is given by:

$I = I_{ph} – I_D - I_{sh}$

$I = I_{ph} – I_o [\exp (q V_D / nKT)] – (V_D / R_S)$

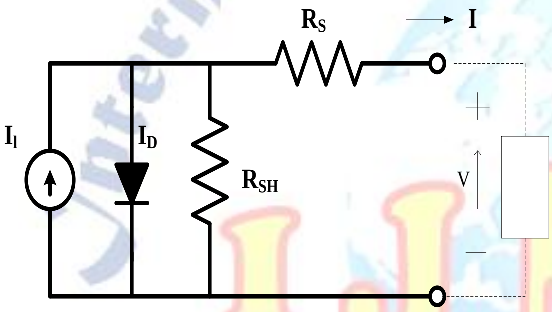

Figure 2: Equivalent circuit of PV Module

Power output of solar cell is P = V * I

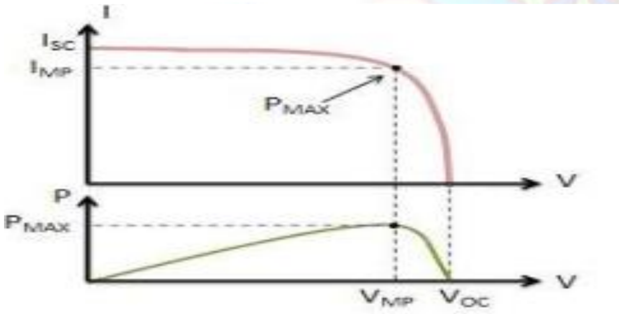

Figure 3: Output characteristics of PV Array

MAXIMUM POWER POINT TRACKING METHOD:

The irradiance and temperature curves are the two most vital factors which influence the output power characteristics of the PV system. And these two are momentarily maintained by solar irradiation and temperature. As discussed, there will be blunt changes in the values of solar radiation during the day as shown in Figure 1. A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the thevenin impedance of the circuit (source impedance) matches with the load impedance. In this way, Maximum power point tracking technique is necessarily used to improve the efficiency of the solar panel.

As the solar panel voltage /current increases, the PWM generator increases its repetition rate thus resulting in increased output current. At the same time, additional voltage is applied to the inductor thus increasing its charge current. Where the initialization is based on voltage and power calculations that are based on current and voltage values acquired from sensors [9]. Once the actual power is calculated, then the next cycle of the measurement is compared to previous value to change the reference voltage V_{ref}.

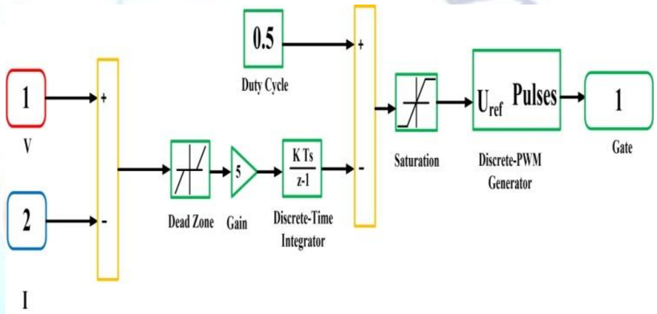

Figure 4: DC-DC converter MPPT Controller

PROPOSED SYSTEM:

The active power pumped by grid tied solar inverter into the grid is a function of solar insolation. This means that the amount of active power pumped into the grid will be lower than the designed rated capacity of solar inverter if the solar irradiance is less (which actually happens as the solar irradiance is not uniformly maximum throughout the day). This leads to underutilization of the inverter resource. If the inverter is programmed to provide reactive power also in addition to active power (based on solar irradiance availability) then the inverter can be operated at its rated capacity even when the solar resource is not fully available. Reactive power compensation through solar inverter is an interesting method to manage network voltages through reactive power injection and absorption.

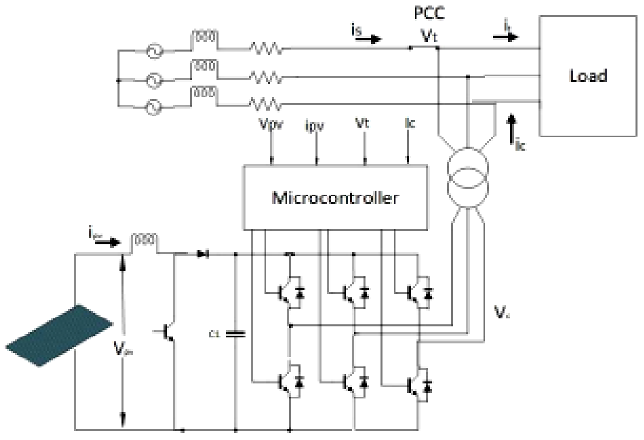

Figure 5: Structure of Grid Connected PV system for Reactive Power Control

SPACE VECTOR MODULATION TECHNIQUE:

A different approach for getting gate triggering signals instead of general pulse width modulation technique is based on the space vectors generated by the system two phase vector components d, q axis.

Fig: 6 shows the space vector representation of the adjacent vector V1 and V2 with 8 space vector switching pattern positions of inverter as shown in figure.

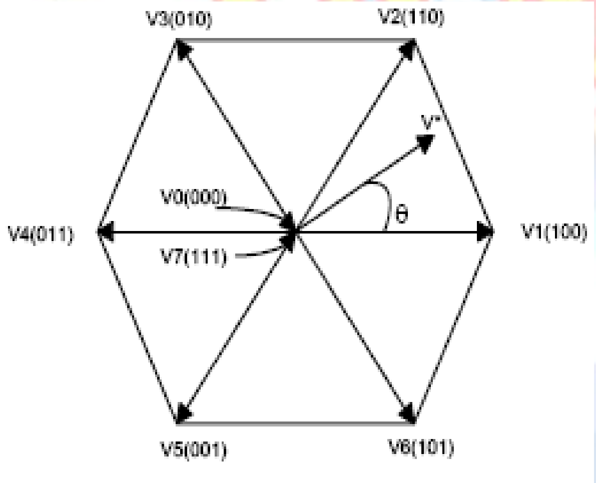

Fig 6: Space Vector Modulation Technique

Generally, the Space Vector Modulation Technique is one of the most popular and important technique in pulse width modulation methods of the three phase voltage source inverters for technique, we get the less harmonics in the both output voltage and output currents of the applied ac motors. The space vector modulation technique is used in this paper for creating the reference vectors generated by modulating the switching time sequence of space vectors in each of six sectors as shown in figure 6. From figure 6, six switching sectors are used for inversion purpose and two sectors are behave like a null vectors.

Space vector modulation can be implemented by the following procedures:

1. Transformation of three phase quantities into two phase quantities.
2. Determine time duration T1, T2 and T0.

The reference signals for voltages and V0 to V7 and switching time sequences are generated by the following expression

$V^* \, Tz = V1 \, {}^*T1 + V2 \, {}^*T2 + V0 \, {}^*(T0/2) + V7 \, {}^*(T0/2)$

RESULTS AND DISCUSSION:

The complete grid connected hybrid system is given in figure 1. The PV system consists of PV module in series mode and boost converter.

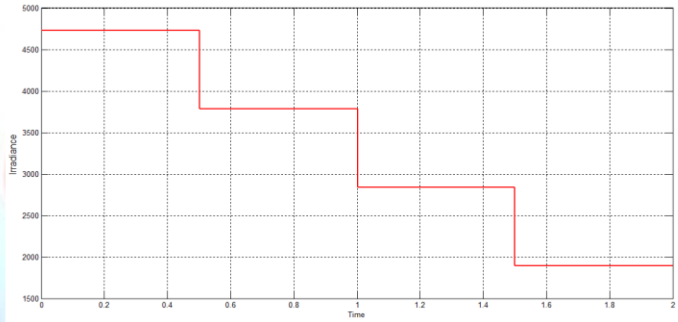

Figure 6: Simulation Waveform for Solar Irradiance (W/m2)

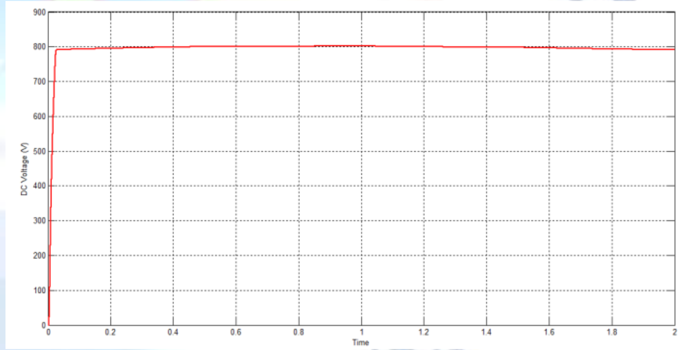

Figure 7: Simulation Waveform for Solar DC Voltage

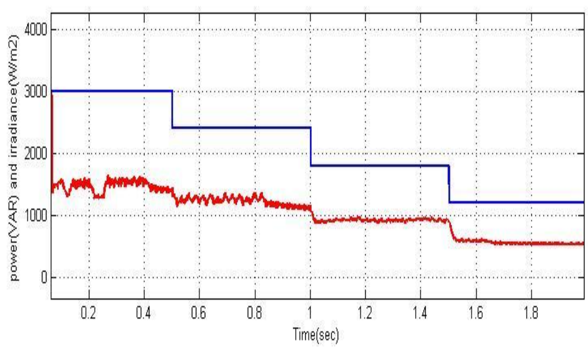

Figure 8: Simulation Waveform for Active and Reactive Powers of PV System

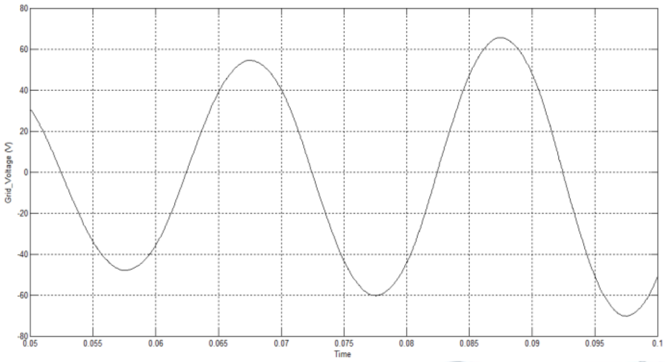

Figure 8: Simulation Waveform for Grid Voltage

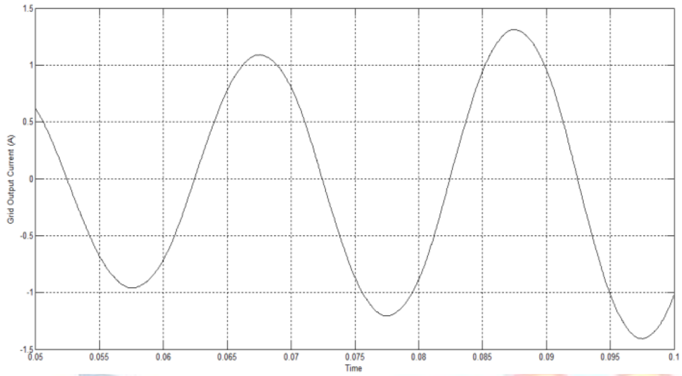

Figure 9: Simulation Waveform for Grid Current

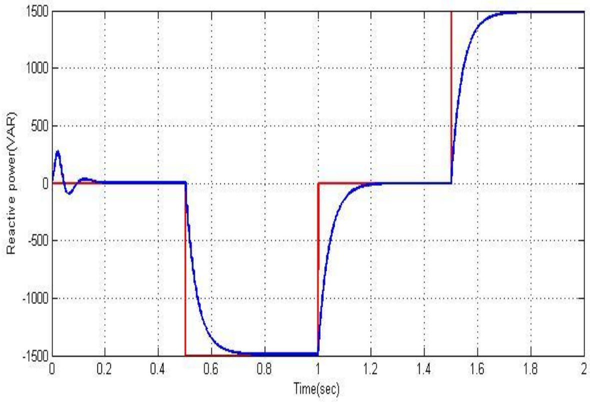

Figure 10: Simulation Waveform for Reference and Actual Reactive Power under fixed Q-Mode

Table-1: Comparative Analysis Between Conventional and SVM Controller

PARAMETER	PWM CONTROLLER	SVM CONTROLLER
POWER FACTOR	0.79	0.84
DC VOLTAGE (V)	495	847
ACTIVE POWER (W)	750	750
REACTIVE POWER (VAR)	385	236.3
LOAD VOLTAGE (V)	232	221
LOAD CURRENT (A)	17.5	40
THD (%)	7.27	0.32

CONCLUSION

This article provides a SVM controller based grid tied PV system for reactive power compensation. It also gives an idea about grid-tied or standalone mode of operations and types of preferable converters for each MPPT technique. This review has included many recent hybrid MPPT techniques along with their benefits. This review is expected to be a useful tool for not only the MPPT users but also the designers and commercial manufacturers of PV systems. From this study we observe that both P&O and IC were developed based on the extreme value theory. Ideally, they can track the maximum power point accurately based on the maximum value condition. However, both rely on the numerical approximation of differentiation, of which the stability and accuracy is difficult to be guaranteed in practical applications considering noise and quantization error etc. The continuous oscillation around the optimal operating point is an intrinsic problem of the algorithms.

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