

# A high performance hybrid MPPT control scheme for a grid connected PV system based three level NPCMLI

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## Abstract

This paper discusses about usage of novel control strategy to extract maximum power in case of solar energy conversion system for renewable energy system applications with the power electronic technology based novel 3 level neutral point clamped inverter. Photovoltaic is one of the important renewable energy sources. Compared to other renewal energy sources photovoltaic energy is clean and abundantly available. Solar power is considered a very promising source for electric power generation. It is generally seen that the renewable energy system is highly stochastic in nature and does not guarantee continuous power throughout the period. The solar based renewable energy resource has to be coupled with the existing conventional grid which might overcome the stochastic behavior of the non conventional resources. To meet the demand of the various types of customers, the proposed combination or generation mix is highly desirable and ray of hope for future generation. The efficient usage of solar based power generation is certainly possible when interfaced with the existing grid and meet the load requirement of diversified customers who are dependent on electric power.

Low efficiency of the solar PV module leads to research and improvement about control technology of different sub-modules of solar based renewable energy generation system interfaced with the existing grid. Generally, the photovoltaic system rating is constrained by the efficiency of percentage output power obtained from the PV panel. In order to achieve this objective, controller to extract the maximum power from solar panel is designed and incorporated in the system known as Maximum power point tracking (MPPT). The return on investment is feasible with various constraints like environmental factors, other internal and external factors, only when the power output is optimum and maximum with the existing operating conditions.

The maximum energy production that is power should be extracted from the solar panel in the given conditions. This process is called maximum powerpoint tracking. The point at each the proposed aim is reached, is called point of maximum power. The efficiency of the entire photovoltaic energy generation depends on the operating characteristic point. The load should ultimately get the optimum possible power obtained from the photovoltaic generation at the operating characteristic point [5]. Therefore, there should be some control logic or control technique in form of a suitable controller which is designated as maximum power point tracking (MPPT) controller. This controller is designed in such a way that the maximum power is obtained from the photovoltaic module.

In this work, Direct Prediction Method and P&O is implemented as a hybrid MPPT control scheme grid connected PV system based NPCMLI. MLI helpful in increasing dynamic performance of the PV system with the existing operating conditions. This MLI offers less harmonic disturbances and goes near to maximum possible power factor operation i.e. 1. The results are verified in Matlab /Simulink environment.

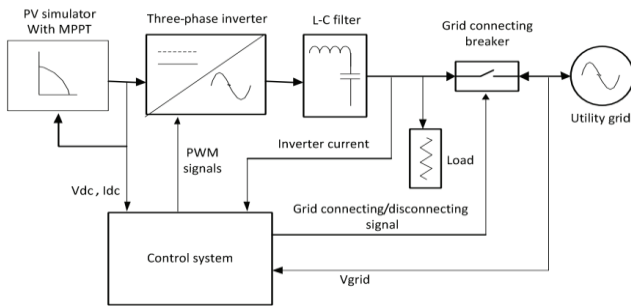
**Keywords:** PV System, Hybrid MPPT, NPC MLI, Grid, Power Quality

## 1. Introduction

In the modern times, the exclusive and continuous demand for safe, clean, economical, and non depleting energy reserve has increased consistently since the fossil fuels have created environmental issues. As a result, alternative energy sources are determined for the problems, such as renewable energy based solar power harnessing and fuel cells. Among the variety of renewable energy resources available, solar energy has great attention because of its abundance and pollution-free conversion to electricity through renewable means of energy generation. MPPT requires more number of PV arrays installation and power electronic circuits to improve protection level, stability, reliability and power quality. Also for safety purpose, most of the PV systems requires galvanic isolation[1].

Regards in power converters through PV to grid connected application; the voltage source inverter is a most famous topology. Sometimes these schemes have some major limitations when used for the PV application. The VSI has been operated under step down characteristics. Therefore, to step up the low voltage output from the PV array, extra power electronic DC / DC converters are required. The VSI-based PV system produces poor performances such voltage stresses, current harmonics and discontinuous current flow on the grid-side. The CSI (current source inverter) has boosting (stepping-up) capacity, mainly it can operate with a low-voltage DC source on the DC side with the help of inductor windings. The CSI ensures a low-ripple current at the interfaces of both PV panels and the inverter [2]. The big inductors in cascade to the DC source damage the devices under open and short circuit conditions.

Generally, the inverter fed PV system should be employed by controlled switches for DC to AC conversion and the switches require frequency based PWM signals [3]. Further, the inverter fed PV system is operated under two more classifications. One is nonisolated (transformer less) grid-connected inverter PV system and is shown in figure 1.



**Fig. 1:** Transformer less solar based renewable energy resource with the existing grid

Thus, the inverter is usually interfaced to the utility grid through a transformer. However, isolated and non-isolated fed PV inverter topologies have also been implemented for single-phase grid-connected PV inverter applications. More voltage and current harmonic problems can occur in it.

These drawbacks of PV fed basic inverter can be overcome by impedance network interfaced inverter. The grid-connected inverter should meet the following requirements [4].

- Improved voltage gain.
- The perfect sinusoidal voltage has to be generated at the output of the inverter
- The harmonic percentage compared to the fundamental should be minimum in case of current waveform of the inverter.

Those requirements should be satisfied by using impedance network for voltage stability, and multilevel inverter for harmonic elimination. The Multilevel inverter can draw the input current with low distortion; therefore research has investigated the PV-Grid connected operation through various types Multi Level Inverters.

Furthermore, a few regulation and control systems have been produced or embraced for multilevel inverters, including the accompanying: multilevel sinusoidal (PWM), multilevel specific disturbance mitigation, and space vector modulation[5], [20]. They offer enhanced yield waveforms, reduced rating of filter, bring down EMI, bring down harmonic percentage compared to the fundamental, and others [5]– [10]. In the recent times, multilevel inverters have turned out to be more appealing for specialists and makers because of their points of interest over ordinary three-level pulse width-regulated (PWM) inverters. The three topologies for multilevel inverters are as per the following: 1) diode clipped (neutral cinched) [11]–[13]; 2) capacitor braced (flying capacitors) [14]– [16]; and 3) H-bridge type inverter [17]– [19].

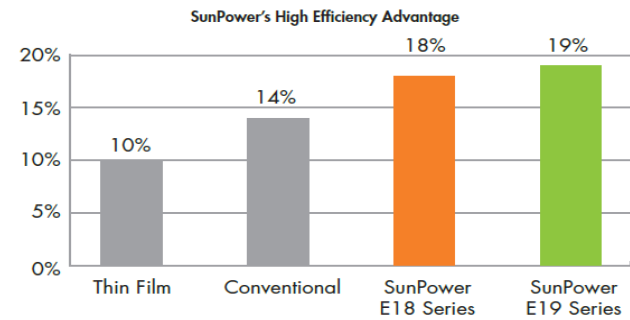
## 2. Proposed system

In this work, hybrid MPPT algorithm for Grid connected PV system with multilevel inverter are developed and compared under different input/output conditions i.e. under different irradiance, fault, islanding etc. Details of various components of developed system are as follows:

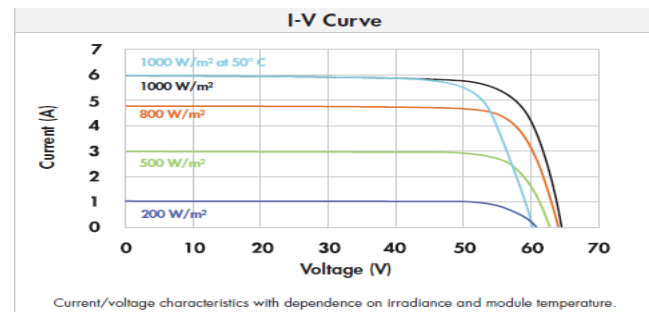
### 2.1. Solar module

Sun based module comprises of PV cells which create electric power when enlightened by daylight. Sun based PV module considered for assessment of proposed framework is Sunpower-305. The SunPower TM 305 Solar Panel gives the present most noteworthy proficiency and execution. Using 96 SunPower all back-contact sun oriented cells, the SunPower 305 conveys an aggregate board transformation productivity of 18,7% as shown in fig 2. The 305

board's diminished voltage-temperature coefficient, antireflective glass and uncommon low-light execution traits give extraordinary vitality conveyance per crest watt. I-V and P-V characteristics are shown in fig 3.



**Fig. 2:** Efficiency of different types of materials used in PV cells

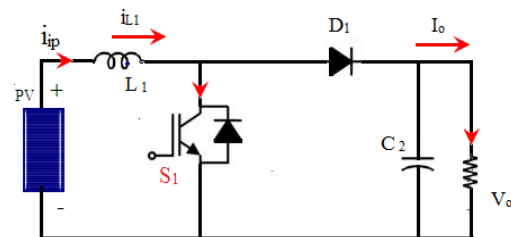


Current/voltage characteristics with dependence on irradiance and module temperature.

**Fig. 3:** I-V and P-V curves of PV cell at different irradiance

### 2.2. Boost converter

The main role of the Boost DC-DC converter is to insure Impedance adaptation between the PV module and the grid, Set the PV operating point (VPV, IPV) to MPP and efficiently step up the PV Module voltage (VPV) to a higher DC voltage VDC of 500V. Fig 4 shows the DC-DC boost converter circuit.



**Fig. 4:** DC-DC boost converter

### 2.3. Inverter

Inverter efficiently generates AC output in phase with the AC grid voltage and balances the average power delivery from the PV module to utility grid. It converts the DC voltage of 500V to three phase AC voltage of 260Vac. As per scope of thesis the proposed system model will be developed using MATLAB/Simulink. Different system components will be modelled and tested in Simulink to validate the system operation. The objectives which are explained below will be validated based on the simulation results. A reference 200W laboratory prototype will be developed for investigation purpose. The prototype system will be microcontroller based PV system which will be implemented using MPPT techniques analyzed in the thesis.

The MPPT techniques will be selected based on the criteria that it should be efficient in operation and also it should be easier from implementation point of view.

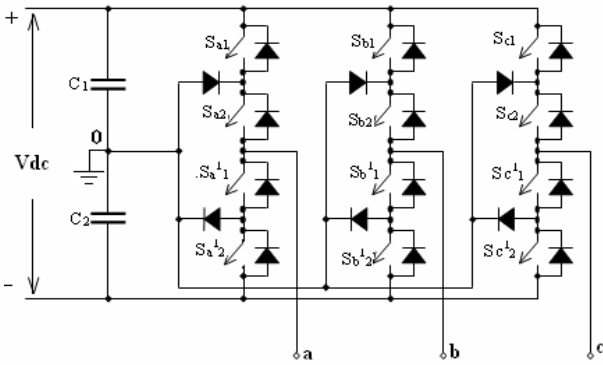


Fig. 5: Three level neutral point clamped multilevel inverter

### 3. Neutral point clamped multilevel inverter

Figure 6 shows the complete schematic diagram of the solar based renewable energy resource has to be coupled with the existing conventional grid with resistance and inductance load.

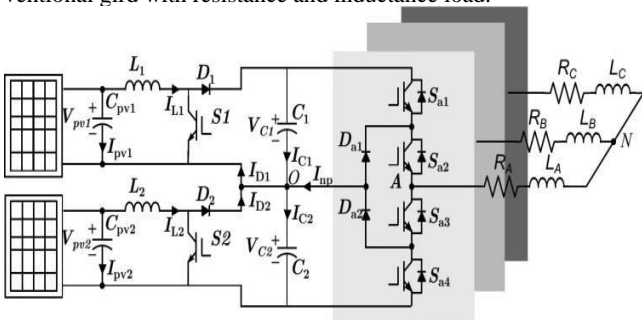


Fig. 6: Proposed schematic diagram

Figure 7 presents the modeling of the proposed circuit in terms of basic electrical elements.

The NPC inverter switches  $S_{j1}$ ,  $S_{j2}$ ,  $S_{j3}$ , and  $S_{j4}$  are represented by the switching states  $q_{j1}$ ,  $q_{j2}$ ,  $q_{j3}$  and  $q_{j4}$ , respectively. The switching states  $q_{j3}$  and  $q_{j1}$  are complementary and so are  $q_{j4}$  and  $q_{j2}$ . Switches  $S_1$  and  $S_2$  of the boost converters are represented by the switching states  $q_1$  and  $q_2$ , respectively.

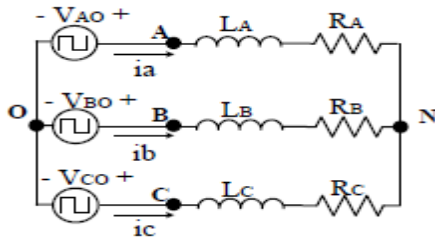


Fig. 7: Modeling of proposed circuit

Applying the basic electrical laws, the following equation can be obtained

$$v_{jo} - R_1 i_j - L_1 \frac{di_j}{dt} - v_{on} = 0 \tag{1}$$

where  $j$  is the corresponding phase

$$v_{on} = \frac{(v_{ao} + v_{bo} + v_{co})}{3} \tag{2}$$

$$v_{jo} = (q_{j1} + q_{j2} - 1)(v_{c1} + v_{c2})/2 \tag{3}$$

#### PWM strategy and Dc-Link control

In order to achieve the same DC voltage across both the capacitors, the PWM based technique is depicted in Fig.8.

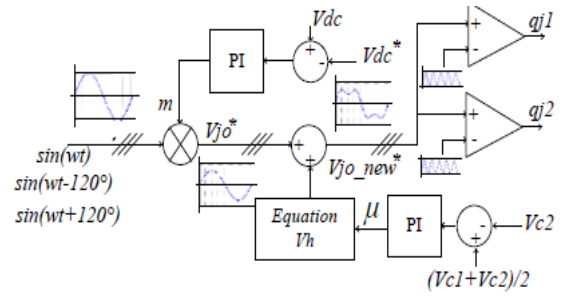


Fig. 8: Control circuit of proposed method

The dc-interface voltage ( $V_{dc}$ ) level control is acquired by direction of the sufficiency file  $m$  through PI.  $m$  is the proportion between adjusting signal and the bearer plentifulness and decides the present an incentive to be infused in the dc-interface with the goal that its required level is kept up. Increase of  $m$  by the three unitary sinusoidal signs stage moved of 120 degrees brings about the three reference voltages  $v_{ao}^*$ ,  $v_{bo}^*$  and  $v_{co}^*$ . With the target of adjusting the voltages of the individual capacitors, a zero-arrangement flag  $v_h$  is added to the three reference voltages. The zero arrangement flag is characterized in [21], so that

$$v_h = (1 - 2\mu) \frac{V_{DC}}{2} + \mu v_{max} + (1 - \mu) v_{min} \tag{4}$$

where:

$$v_{max} = V_{dc}/2 - \max(v_{ao}^*, v_{bo}^*, v_{co}^*);$$

$$v_{min} = -V_{dc}/2 - \min(v_{ao}^*, v_{bo}^*, v_{co}^*);$$

$\mu$  is the distribution ratio.

### 4. Results and discussions

In this section, the performance of the proposed hybrid MPPT with Neutral Point Clamped Multilevel Inverter is evaluated under different conditions using simulation. The simulated system configuration is shown in figure 9

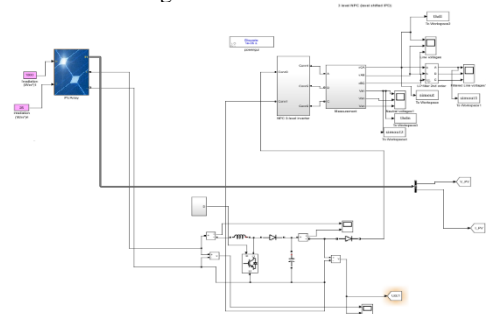
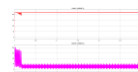
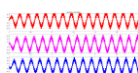


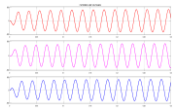
Fig. 9: Overall simulation diagram of proposed PV system



(a)



(b)



(c)

Fig. 10: (a) PV Panel voltage and current (b) phase voltages for NPCMLI (c) filtered voltages

## 5. Conclusion

The solar based renewable energy system coupled with traditional grid connection with the help of NPCMLI and the proposed novel MPPT control technique is presented in this paper. The balance in the dc link voltages is to be maintained during unshaded as well as partial shading conditions. The dc connect voltage of the capacitors is achieved although there is 1/10 th fluctuation in the irradiance, the proposed control scheme effectively takes care of it. The insulation and temperature levels fluctuate, but the scheme exhibits satisfactory values of percentage of harmonics present in the current as well as voltage waveform with reference to the fundamental and well within the standard tolerance limits. The harmonic order as well reduction in the losses due to switching during operation of the converters, losses due to high frequency in the system and stress to thermal effect has been studied in the paper. The inverter operation and the dc link voltage is satisfactory with the proposed scheme. The efficient usage of solar based power generation is certainly possible when interfaced with the existing grid and meet the load requirement of diversified customers who are dependent on electric power.

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