Grid Connected PV System Based On SMC Based Multilevel Inverter

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***Abstract*— This paper presents transformerless multilevel inverter topology with sliding mode control (SMC) for single-phase grid-connected PV applications. the elimination of line frequency transformer is possible without impacting system characteristics related to grid integration, ground leakage current, etc. This paper presents the design, modeling, and simulation of the sliding mode control gives simple implementation, and better performance under load disturbance and parameter variation i.e., it guarantees robust performance. The results of the proposed controller compared with the Proportional plus Integral (PI) controller**

Keywords - Solar PV, Buck-Boost Converter, Transformerless Multilevel Inverter, SMC control, PI control.

1. INTRODUCTION

The electricity demand is increasing day by day as the population increases. India Ministry of New and Renewable Energy, Government of India has set a target of 100 GW of grid-connected PV generation power and is working towards achieving 500 GW of installed electricity capacity from PV by 2030 [5]. Renewable energy sources are fuel cells, photovoltaic (PV), solar, and wind. Solar photovoltaics is the most considered lower system cost and no greenhouse gas emissions are released into the atmosphere [1]. Also, operational costs are quite low compared to other forms of power generation. The power source is not required, and this means that solar power can generate large amounts of electricity. Generally, inverters are used for generating solar PV power into the grid [1]. Usually, a transformer is used to provide galvanic isolation between PV-fed inverters. However, the use of a transformer the circuit makes massive, unwieldy, as well as costly. The overall efficiency is also reduced by the presence of a transformer.

Fig.1 shows the block diagram of transformerless multilevel inverter topology. The advantages of this topology include higher efficiency, lower cost, reduced THD, and ease of implementation. However, the inverter needs to be controlled for Maximum Power Point Tracking (MPPT) to extract maximum power from the PV array and grid synchronization. In this type of topology PWM technique will be introduced to generate the duty cycle and The load side ground terminal will connect to the midpoint of the source terminal Because of this unique connection the oscillation in the PV terminal voltage becomes very low.

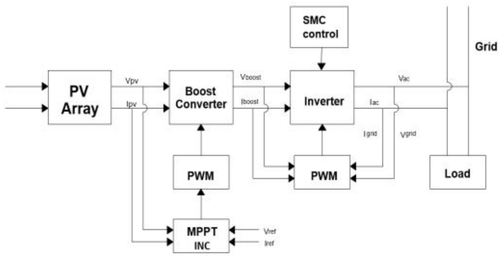


Fig 1: Block diagram of transformerless multilevel inverter topology

The existing system with a novel transformer less inverter using a PI controller for close loop operation is easily available and simple to design but Total Harmonic Distortions(THD) using this system are high. Also, in the PI controller, the value of KP and KI is constant. By keeping KP and KI constant, the harmonic distortion appeared at the load side and created some problems.

To overcome the above problems, we are using sliding mode control on the inverter side to reduce the total harmonic distortion and using the INC Algorithm in MPPT to exact maximum power from the PV array, grid synchronization, and AC side control for active and reactive power transfer to the grid. In this topology, we will propose a buck-boost converter to reduce the voltage gain requirement at the boost stage. The multilevel inverter topology, in Section II, presents the literature review, the methodology is presented in Section III, Section IV presents simulation and results and in Section, discusses the future scope major conclusion of multilevel inverter topology.

2. LITERATURE REVIEW

Mini Rajeev and Vivek Agarwal [2016] they are present the closed loop of a novel transformerless inverter topology for a single phase grid connected PV system. The advantages of this topology are long operational life, buck boost capability, low THD of the output current

Pratik Kumar Kar, et. Al [2], [2021] In this paper PI controller is adopted for the presented multilevel inverter topology. This topology tries to reduce the total harmonic distortion on the output side. It reduces the requirement of the gate driver circuit and additional complexity to the circuit. It also reduces the multilevel inverter cost.

Sandeep V. Ambesange [1], et. Al [3], [2013] In this paper, the application of sliding mode control is used for speed control of DC motor drives. In this paper, show the disadvantage of the PI controller. As stated earlier, the PI controller can be tuned for better performance but the compromise between overshoot and settling time. On the other hand, there is no such problem with tuning in the SMC and the output quality of the controller is far better than the PI controller.

N V Uma Maheswari, et. Al [2], [2022] In this paper the boost converter topology with linear Incremental Inductance (INC) algorithm in maximum power point tracker (MPPT) is used to provide maximum power from the PV panel to the grid. The novelty of this paper is to provide a simple and effective calculation of the INCMPPT algorithm.

3. METHODOLOGY

The multilevel inverter topology consists PV array, SMC control, inductor, and DC link capacitor. The multilevel inverter is used to improve the system quality.

Table 1: ratings of the component

Components	Rating
PV array	380~700 V
inductors	110 µH, 5mH
Filter Capacitor	47 µF, 20 µF
Switch S_1~S_6	IRG4PH40U

3.1 Structure and Operation Principal

Transformerless multilevel inverter. Topology has four important modes. Modes 1 & 2 operate for the positive half-cycle of the proposed inverter topology and modes 2 & 3 operate for the negative half-cycle of the proposed inverter topology.

Mode 1:- This mode of operation helps in powering the grid in the positive half cycle. During this mode, the switches $S_{1,}$ $S_{2,}$ and S_3 are turned ON. When S_1 is ON, L_1 stores the energy from the PV source, and C_1 discharges through L_2 and the grid via switch S_3 and S_4

Mode 2:- In this mode S_1 is OFF, freewheeling of energy stored in the coupled inductor gets transferred to the auxiliary capacitor C_1 through diodes D_2 and D_3. L_2 discharges from the grid and switches S_6.

Mode 3:- This mode of operation helps in powering the grid in the negative half cycle. The switch S_1 is operated in the same way during mode 3. In the negative half cycle, the capacitor C_1 discharges through $S_{1,}$ $S_{2,}$ $S_{5,}$ and grid. L_2 transfers stored energy to the grid through S_5

Mode 4:- In this mode, the freewheeling of energy stored in the coupled inductor gets transferred to the auxiliary capacitor. Energy transfer from C_1 and L_1 happens through diodes D_2 and D_3

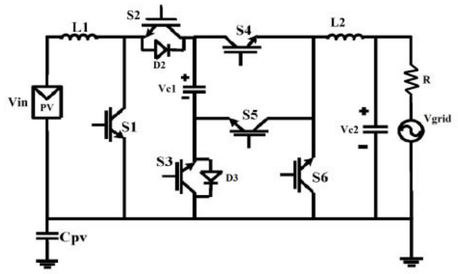


Fig 2:- circuit diagram of Proposed Topology

Table 2: Switching pattern of the topology

	S_1	S_2	S_3	S_4	S_5	S_6	D_2	D_3
Mode 1	1	0	1	1	0	0	0	0
Mode 2	0	0	0	0	0	1	1	1
Mode 3	1	1	0	0	1	0	0	0
Mode 4	0	0	0	0	1	0	1	1

3.2 Control Design

INC MPPT Algorithm:

The inverter needs to be controlled for Maximum Power Point Tracking (MPPT) to extract maximum power from the PV array and grid synchronization. The Incremental Conductance (INC) algorithm is one of the popular methods to track the MPP from the PV array. The main advantage of this algorithm is to minimize the output power from a PV panel by continuously adjusting the operating voltage and current to track the maximum power point

Conductance Calculation:

The INC algorithm calculates the conductance of the solar panel at the current operating point. Conductance (G) is the ratio of a derivative of power (P) and voltage (V)

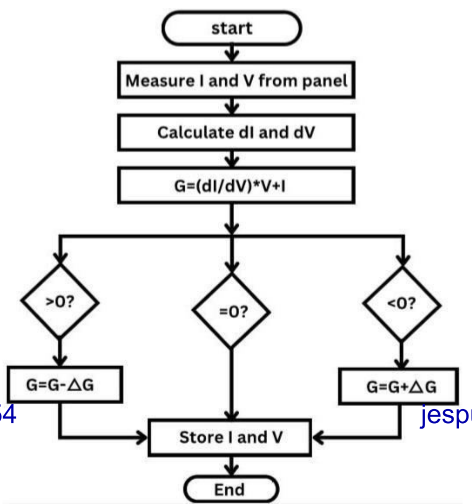
$$G = \frac{dp}{dv} = \left(\frac{dI}{dv}\right) \times V + I$$

Where, $\frac{dp}{dv}$ = incremental change in power

$\frac{dI}{dv}$ = incremental change in current

V = Voltage

I = Current



After calculating the conductance, the algorithm compares the calculated conductance with the instantaneous conductance. The MPPT checks whether INC is zero or not. If it is zero it indicates that the PV system is already operating at the MPP. However, incremental conductance is not zero, it means the PV system is away from the maximum power point.

Fig 3 :- Flowchart of INC algorithm

SMC control :

A sliding mode controller is suitable for a nonlinear system. The advantage of the sliding mode controller, its gives that guarantees robust performance. SMC controller design provides a systematic approach to the trouble of maintaining stability and satisfactory performance in the presence of systems imperfection. In this controller, the parameters vary according to system conditions [3]. SMC controller is turned to a grid frequency of 50Hz. This ensures high loop gain at the grid frequency

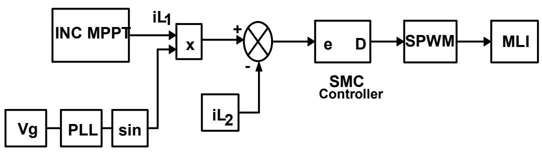


Fig 4: Block diagram of controller

Fig 4 shows the block diagram of the SMC controller, the error detector detects the error from the PV source and the grid. Grid is synchronized with the help of phase locked loop (PLL). After detecting the error, the SMC controller solves the error and sends a signal to the PWM generator. PWM generates the pulse and sends the output to the multilevel inverter.

3.3 Converter Design

Multilevel Inverter:

Multilevel inverter is used in electronics to convert DC current into AC current. Various types of multilevel inverters include cascade H bridge inverters, flying capacitor inverters, etc. In this topology, we are using 7 level cascade H bridge inverter to produce 7 levels of voltages in its output waveform. This inverter provides smoother output for various appliances like renewable energy, motor drive, and grid tied inverter. In fig 2, 4

IGBT switch is used as an inverter S_3, S_4, S_5, and S_6 and is connected to H bridge. The advantage of multilevel inverters is to reduce the total harmonics distortion and enhance efficiency.

Boost Converter:

The boost converter is a type of chopper or DC to DC converter and it is also known as a "Step-Up Chopper". Boost converter gives the output voltage greater than the input voltage. In DC to DC circuit, power MOSFET, IGBT, BJT, etc. are used as a switch. In this topology, we are using two boost converters i.e., S_1 and S_2 and, L is connected in series with the PV array as shown in fig 2.

4. SIMULATION AND RESULTS

4.1 Simulation Model

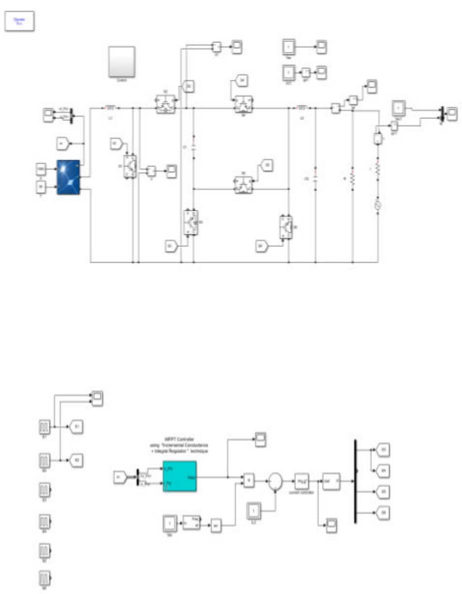
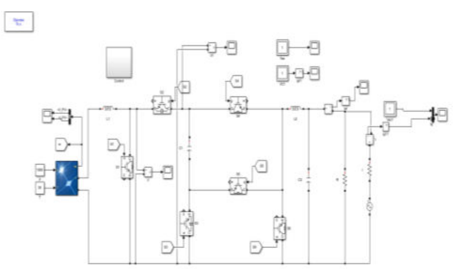


Fig 5: Simulation model of PI controller (Case I)



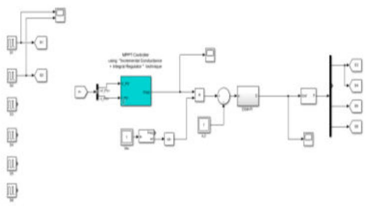


Fig 6: Simulation of SMC controller (Case II)

4.2 Results and Discussion

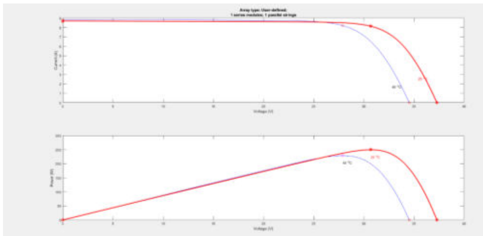


Fig 7: Characteristics of INC algorithm

Fig 7 shows the characteristics of INC algorithm with continuously tracks output power of the PV panel and adjusts the operating point to maintain maximum power output. It does this by comparing the immediate change in power with the immediate change in voltage or current

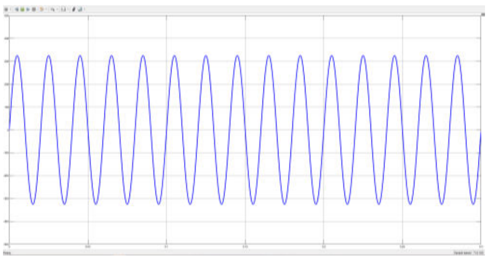


Fig 8 (a): Inverter voltage of PI controller (Case I)

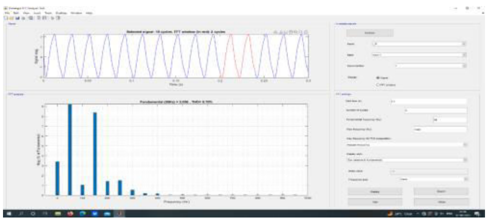


Fig 8 (b): FFT analysis of PI controller (Case I)

Case I: Fig 8 (a) and (b) show that the inverter voltage of the PI controller with THD 8.70%

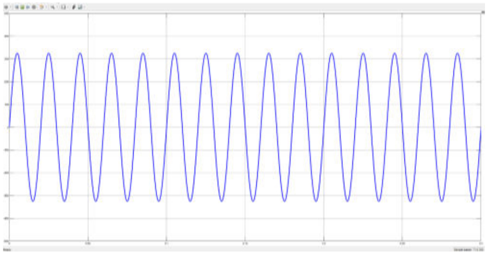


Fig 9 (a): Inverter voltage of SMC controller (Case II)

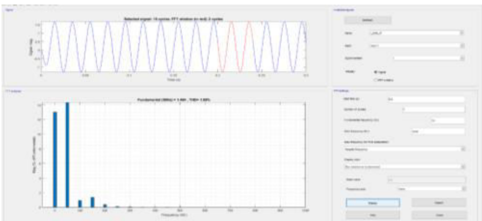


Fig 9 (b): FFT Analysis of SMC Controller (Case II)

Case II: In fig 9 (a) and (b), show the inverter voltage of the SMC controller with THD 1.69%. From figures 8 (b) and 9 (b) it can be observed that the total harmonic distortion (THD) of SMC is less than the PI controller and the response of SMC is better than the PI controller.

4. CONCLUSION

A transformerless multilevel inverter topology with sliding mode control for a single-phase grid-connected PV system is proposed in this paper with reduced conduction losses. The main objective of this topology is to minimize the total harmonic distortion (THD) at the load side using SMC control by replacing PI control and enlarging the efficiency of the system. Due to the INC algorithm property, the transformerless inverter tracked the maximum power from the PV source under the wide voltage variation.

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