Switched Capacitor Inverter for PV Systems

U. Kavitha, R. Ramaprabha, S. Malathy

Abstract— Renewable energy-based power generation has gained more attention in the recently due to the ever-increasing need for the electrical energy and also due to the pollution caused by burning of fossil fuels for conventional method of power generation. Solar based electrical energy generation is one of the easy and best ways to produce electrical energy. Photovoltaic (PV) panels are used to trap the sun's radiation and convert them into usable electrical energy. The aim of this paper is to model a power conditioner which works on the principle of switched capacitor (SC) with a single stage inverter and gives an ac sinusoidal wave as output. A hardware prototype of the switched capacitor inverter for standalone operation has been implemented. The SC inverter delivers output voltage corresponding to the input supplied. This converter can be used along with both grids connected and standalone systems. The converter is compact and light in weight. The main advantage of the converter is its reduced THD with increased efficiency.

Index Terms— PV systems, Switched capacitor, Inverter, Single stage conversion, SPWM, THD, MatLab .

1 Introduction

Renewable source based electrical power generation has gained attention recently due to ever increasing demand for electrical energy. There are plenty of renewable energy sources available in nature and can be utilized to generate electrical energy. Technology involved in generating renewable energy is clean and it has almost very less amount of environmental impact. Also, there are many manufacturers offering PV panel at low cost making the production of solar based power generation viable [1-2].

The electrical voltage received from PV panels will be of smaller magnitude. In order to enhance the voltage to required level power conditioning circuits are needed [3]. Generally, power conditioning circuit will enhance the lower magnitude signal from PV panel (dc) with the help of MPPT algorithm and convert it to ac voltage. Huang et. al. [4] has given an SC based inverter which has two stages of operation. The SC based dc-dc converter forms the first phase and the five-level cascaded multilevel inverter forms the second phase. Since this comprises of two stages, it leads to decreased output efficiency. The switched capacitor inverter will result in increased efficiency, since the process of boosting and inverting take place in a single stage.

Switched capacitor converters (SCCs) utilize switches and capacitor which are switched between the input source and load. The absence of inductor and transformer makes the switched capacitor-based inverter more advantageous. Since the bulky components are avoided, they are capable of being produced as integrated circuits [5-6]. The SC converters are able to give an efficiency of 90% with wider operating range [7]. This type of converter is chosen over the other conventional converter owing to their solid built and compact size.

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The SC inverter which is fed from a dc source is presented in this paper. The main purpose of using SC based inverter is to increase output efficiency with reduced THD [8-10]. The SC inverter can be operated over a wide range starting form mW to kW. The output of the SC inverter will be proportional to the input source. The simulation work is carried out using MatLab-Simulink tool. Hardware prototype of the same is implemented, and their results are discussed.

2 Summary of The Proposed System

The structure of switched capacitor inverter is represented in the Figure 1.

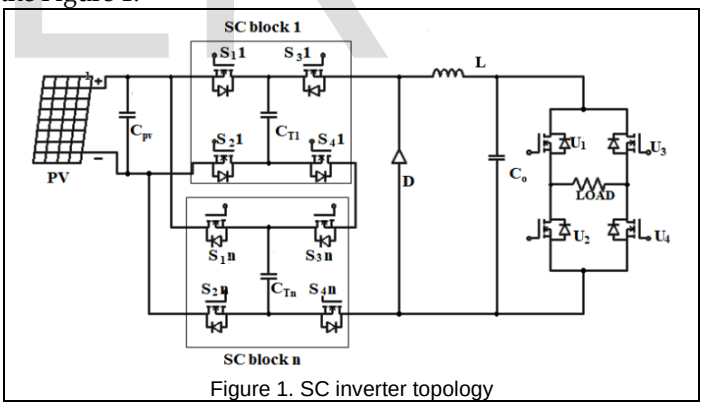

Figure 1. SC inverter topology

The switched capacitor inverter is operated based upon the switching pulse given to the switches. The switches in the SC inverter are triggered according to the SPWM signal produced by comparing the unipolar sine wave with triangular wave at a frequency of 20 kHz. The input side switches (S_1n and S_2n) are turned for a period of D_1s. the output side switches (S_3n and S_4n) are turned on for a period of D_2s. When more than one block of switched capacitor blocks is connected, all the input side switches will be triggered simultaneously and all the output side switches will be triggered simultaneously. There will be a dead time of t_D between switching from input side to output side. A detailed working of the switched capacitor inverter is given by the author in [3].

3 Simulation Results and Discussions

The design procedure of switched capacitor inverter is explained in detail by the author as in [3]. The components are selected according to the values obtained by computing the equations, with the obtained specifications switched capacitor inverter is modelled using Matlab-Simulink tool.

The panel designed in MatLab is in accordance to the panel available in market (SOLKAR Panel – Model No. 3712/0507) and the specifications are as given in the Table 1.

TABLE 1
PV Panel Specifications

Description	Value / Rating
Maximum power (P_m)	36.0 W
Maximum power voltage (V_{mp})	16.56 V
Open circuit voltage (V_{oc})	21.6 V
Maximum power current (I_{mp})	2.25 A
Short circuit current (I_{sc})	2.55 A
Total number of cells in series (N_s)	36
Total number of cells in parallel (N_p)	1

The Switched capacitor inverter parameters are given in Table 2.

TABLE 2
Component Selection for SC Inverter

Component description	Value/ Rating
Input voltage	60V
Output voltage	110rms
Coupling capacitor, (C_{PV})	1800µF
Charge transfer capacitor, (C_T)	33µF
Output capacitor, (C_O)	1µF
Inductor, L	850µH

The switched capacitor inverter is designed in the MatLab-Simulink using the above said parameters and is given in Figure 2. The input side of the switched capacitor inverter is energized by the PV panel. In order to obtain the desired magnitude of 60V, the PV panels are linked serially.

The MatLab model of the SC inverter is evaluated and the output voltage waveform is obtained, as shown in Figure 3. The magnitude of the output voltage obtained is $110V_{rms}$. In order to increase or decrease the magnitude of the output voltage, the input dc voltage can be varied.

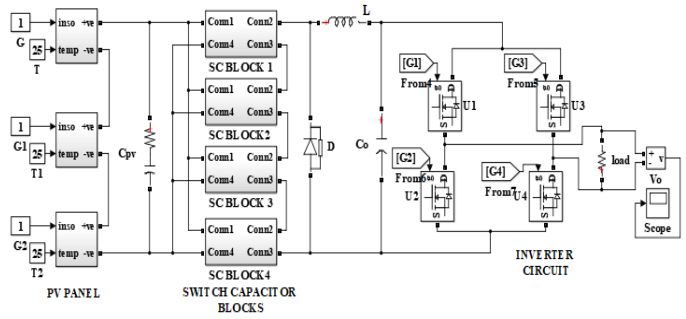

Figure 2. MATLAB model of SC inverter

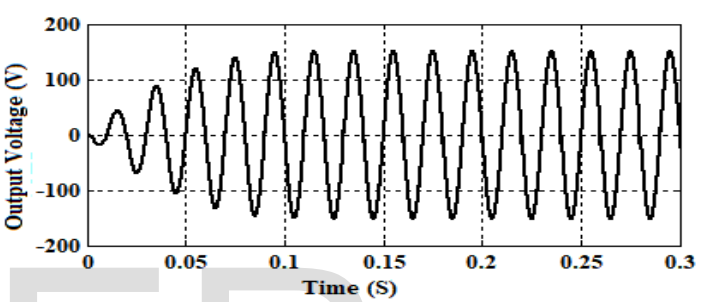

Figure 3. Output sine wave

The harmonic spectrum is shown in Figure 4.

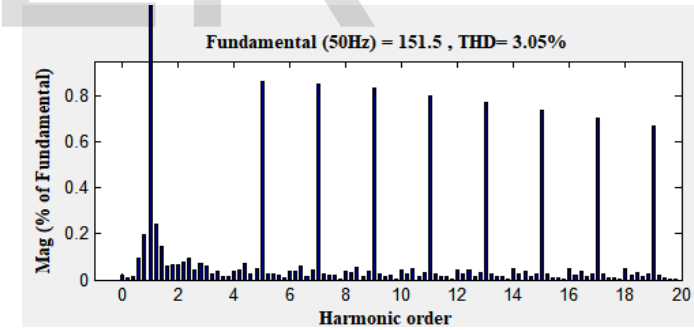

Figure 4. THD study of output voltage waveform

It can be observed that the THD is 3.05% which is in accordance to the standards.

4 Hardware Set-up

The overall schematic of the prototype is given in Figure 5. From the simulation studies it can be inferred that the switched capacitor inverter is capable of producing sine wave as the output at fundamental frequency of 50Hz. To validate the performance of the switched capacitor inverter, hardware prototype is implemented with a single block of SC. The hardware prototype includes the gating circuit, switched capacitor-based inverter with the pulse generated using Arduino Microcontroller.

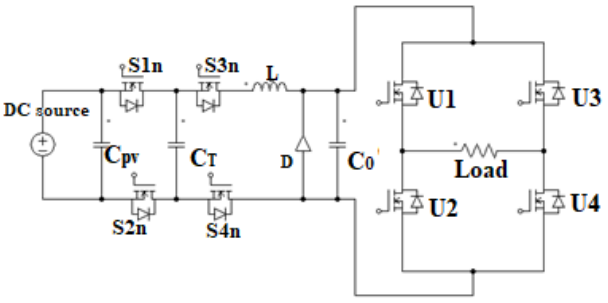

Figure 5. Schematic of the hardware prototype

The proper operation of the hardware setup depends on the pulse generated to trigger the MOSFET switches. The switched capacitor is switched at a frequency of 20 kHz, and the inverter is switched at a frequency of 50Hz. The generated gating pulses are given to their respective switches. The experimental arrangement is as shown in Figure 6.

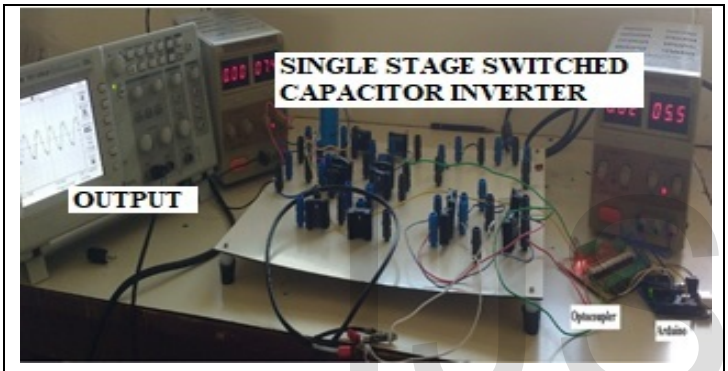

Figure 6. Experimental arrangement of the switched capacitor inverter

The hardware is implemented with single block of switched capacitor inverter, which is basically a buck topology. The output obtained from the developed hardware prototype complies with the requirements. The experimental output waveform of single stage switched capacitor inverter is shown in Figure 7 for an input of 18V. The input dc voltage is converted to ac voltage with a peak to peak voltage of 15 V at a frequency of 50Hz. The number of SC stages can be increased to achieve higher output voltage magnitude.

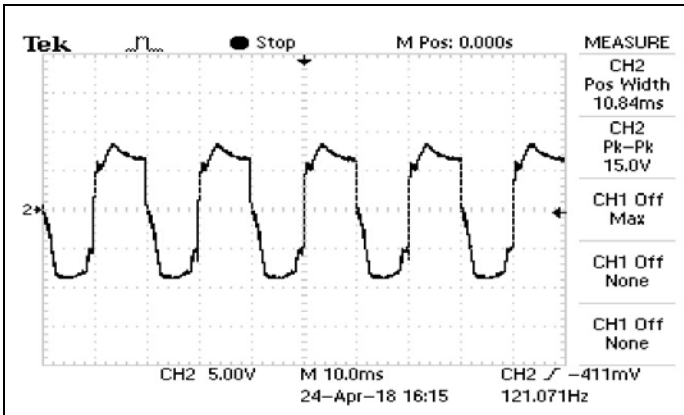

Figure 7. Experimental output waveform of single stage switched capacitor inverter

5 Conclusion

A single stage SC inverter for PV Scheme has been proposed in this paper. The output voltage from the PV source is enhanced by means of four switched capacitor units to get an output voltage of 110Vrms or a peak to peak voltage of 155V. The efficiency is 91.4 % and the THD is less than 4%. Hardware prototype for the same is implemented with a single SC block. The SC based inverters are compact, weightless and the efficiency is almost constant, this makes it possible for them to be used along with solar panels fixed on top of automobiles. It can also be used in remote locations.

The use of several number of MOSFET switches puts the SC based inverter at disadvantage when compared to regular power conditioners. This can be overcome by reducing and integrating the number of switches and their drive circuits in a single chip. This type of switched capacitor inverter can also be used with grid tied connections.

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