

A Novel Solar Power Generation System with a Seven-Level Inverter

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ABSTRACT: This paper proposes a seven-level inverter for a solar power generation system. The new solar power generation system is composed of a dc/dc power converter and a new seven-level inverter. The dc/dc power converter converts the output voltage of the solar cell array into two independent voltage sources with multiple relationships. This new seven-level inverter is configured using a capacitor selection circuit and a full-bridge power converter, connected in cascade. The capacitor selection circuit converts the two output voltage sources of dc-dc power converter into a three-level dc voltage, and the full-bridge power converter further converts this three-level dc voltage into a seven-level ac voltage. The salient features of the inverter are that only six power electronic switches are used, and only one power electronic switch is switched at high frequency at any time

KEYWORDS: Full-bridge power converter, solar cell, seven-level inverter, capacitor selection circuit, dc/dc power converter

I. INTRODUCTION

Solar energy is becoming more important since it produces less pollution and the cost of fossil fuel energy is rising, while the cost of solar arrays is decreasing. The power conversion interface is important to grid-connected solar power generation systems because it converts the dc power generated by a solar cell array into ac power and feeds this ac power into the utility grid. An inverter is necessary in the power conversion interface to convert the dc power to ac power. Since the output voltage of a solar cell array is low, a dc-dc power converter is used in a small-capacity solar power generation system to boost the output voltage, so it can match the dc bus voltage of the inverter. The power conversion efficiency of the power conversion interface is important to ensure that there is no waste of the energy generated by the solar cell array.

Multilevel inverters are mainly classified into three: Diode Clamped, Capacitor Clamped and Cascaded H-Bridge. Diode clamped and flying capacitor multilevel inverters doesn't have asymmetric voltage topology. Asymmetric voltage topology means that it generates more voltage levels with less number of semiconductors and thus increases output performance and system reliability. Disadvantages of diode clamped inverter are limited output voltage and disturbance in charge balance for more than three levels [1]-[3]. In capacitor clamped multilevel inverter, capacitor should be pre-charged. Theoretically this topology gives in finite levels but due to practical limitations gives only six levels of voltage. Disadvantage of this method is that pre-charging of capacitors is necessary and difficult. [4]-[6] In this case the arm cells have different effect on the output voltage. Number of levels depends on number of dc sources attached to it. It does not need diodes and capacitors for clamping. It has asymmetric voltage topology [7]-[9]. Comparison of seven-level inverters is shown in Table.1. Proposed topology uses only six power electronic switches and 2 capacitors. This reduces switching loss and improves power conversion efficiency [10]

The solar power generation system with a seven-level inverter is composed of a dc/dc power converter and a seven-level inverter. The seven-level inverter is configured using a capacitor selection circuit and a full-bridge power converter connected in cascade. The seven-level inverter contains only six power electronic switches, which simplifies

the circuit configuration. Since only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage, the switching power loss is reduced, and the power efficiency is improved. The inductance of the filter inductor is also reduced because there is a seven-level output voltage.

Table.1 Comparison of seven-level inverter

	Diode clamped	Flying capacitors	Classic cascaded H-bridge	Hybrid cascaded H-bridge	Proposed topology
capacitors	6	6	3	2	2
Clamping diodes	10	0	0	0	0
switches	12	12	12	8	6

Paper is organized as follows. Section II describes the circuit configuration. Control block is given in Section III. Section IV presents Matlab simulation results of the inverter. Finally, Section V presents conclusion

II. CIRCUIT CONFIGURATION

Fig.2 shows the setup of the proposed sun oriented force era framework. The proposed sun oriented force era framework is made out of a sun oriented cell cluster, a dc–dc power converter, and another seven-level inverter. The sun oriented cell cluster is associated with the dc–dc power converter, and the dc–dc power converter is a support converter that joins a transformer with a turn proportion of 2:1. The full-connect power converter further changes over this three-level dc voltage to a seven-level air conditioning voltage that is synchronized with the utility voltage. As can be seen, this new seven-level inverter contains just six force electronic switches, so the force circuit is simplified.

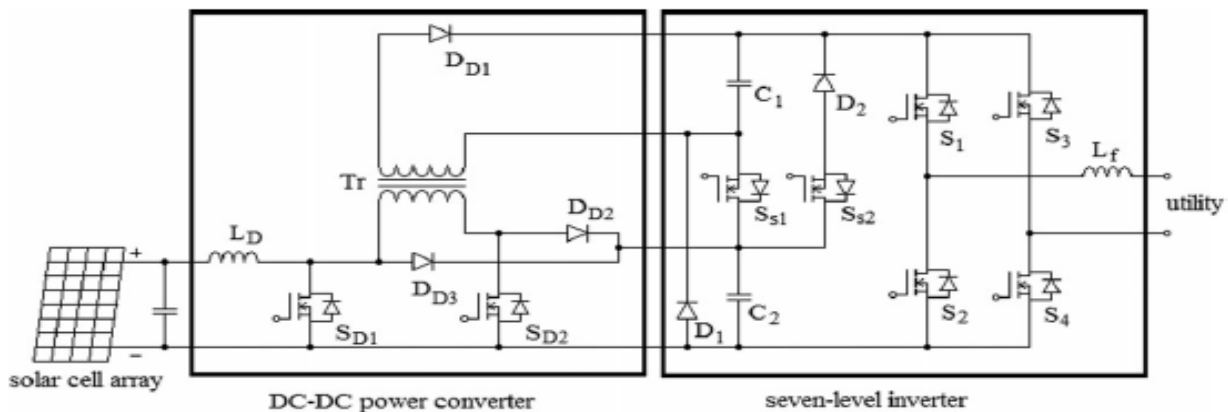


Fig.2 Circuit diagram of solar power generation system with a seven-level inverter

The DC–DC power converter incorporates a boost converter and a current fed forward converter. The boost converter is composed of an inductor L_D , a power electronic switch S_{D1} , and a diode, D_{D3} . The boost converter charges capacitor C_2 of the seven-level inverter. The current-fed forward converter is composed of an inductor L_D , power electronic switches S_{D1} and S_{D2} , a transformer, and diodes D_{D1} and D_{D2} . The current-fed forward converter charges capacitor C_1 of the seven-level inverter. The solar cell array supplies energy to the inductor L_D . Accordingly, capacitor C_1 is connected to capacitor C_2 in parallel through the transformer, so the energy of inductor L_D and the solar cell array charge capacitor C_2 through D_{D3} and charge capacitor C_1 through the transformer and D_{D1} during the off state of S_{D1} Since capacitors C_1 and C_2 are charged in parallel by using the transformer, the voltage ratio of capacitors C_1 and C_2 is the same as the turn ratio (2:1) of the transformer. Therefore, the voltages of C_1 and C_2 have multiple relationships. The boost converter is operated in the continuous conduction mode (CCM).

The voltage of C_2 can be represented as

$$V_{c2} = [1/ (1 - DV_s)] \dots\dots\dots (1)$$

where V_s is the output voltage of solar cell array and D is the duty ratio of S_{D1} .

The voltage of capacitor C_1 can be represented as

$$V_{c1} = 1/ [2(1 - D)V_s] \dots\dots\dots (2)$$

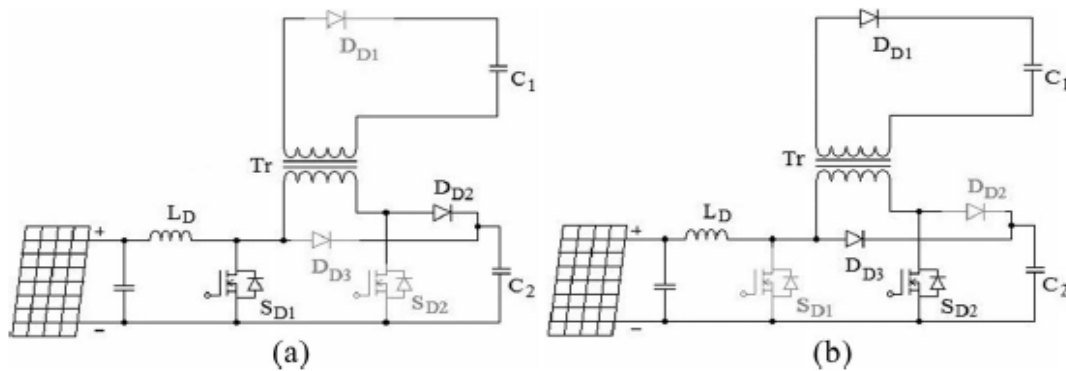


Fig. 3. Operation of dc-dc power converter: (a) S_{D1} is on and (b) S_{D1} is off.

In the proposed dc-dc power converter, the vitality put away in the charging inductance is conveyed to capacitor C_2 through D_{D2} and S_{D1} when S_{D2} is killed. Subsequent to the vitality put away in the charging inductance is exchanged forward to the yield capacitor C_2 and not back to the dc source, the force proficiency is moved forward.

The seven-level inverter is made out of a capacitor determination circuit and a full-connect power converter, which are associated in course. While the voltages of both capacitors C_1 and C_2 in the capacitor determination circuit are consistent and equivalent to $V_{dc}/3$ and $2V_{dc}/3$, individually. Subsequent to the yield current of the sun based force era framework will be controlled to be sinusoidal and in stage with the utility voltage, the yield current of the seven-level inverter is likewise positive in the positive half cycle of the utility. The operation of the seven-level inverter in the positive half cycle of the utility can be further partitioned into four modes, as shown in Fig. 4

Mode 1: C_1 is discharged through D_1 and the output voltage of the capacitor selection circuit is $V_{dc}/3$. At this point, the output voltage of the seven-level inverter is directly equal to the output voltage of the capacitor selection circuit, which means the output voltage of the seven-level inverter is $V_{dc}/3$.

Mode 2: C_2 is discharged through S_{S2} and D_2 and the output voltage of the capacitor selection circuit is $2V_{dc}/3$. At this point, the output voltage of the seven-level inverter is $2V_{dc}/3$.

Mode 3: Since D_2 has a reverse bias when S_{S1} is ON, the state of S_{S2} cannot affect the current flow. Therefore, S_{S2} may be ON or OFF, for avoiding switching of S_{S2} . Both C_1 and C_2 are discharged in series and the output voltage of the capacitor selection circuit is V_{dc} . At this point, the output voltage of the seven-level inverter is V_{dc} .

Mode 4: Only S_4 of the full-bridge power converter is ON. Since the output current of the seven-level inverter is positive and passes through the filter inductor, it forces the antiparallel diode of S_2 to be switched ON for continuous conduction of the filter inductor current. At this point, the output voltage of the seven level inverter is zero

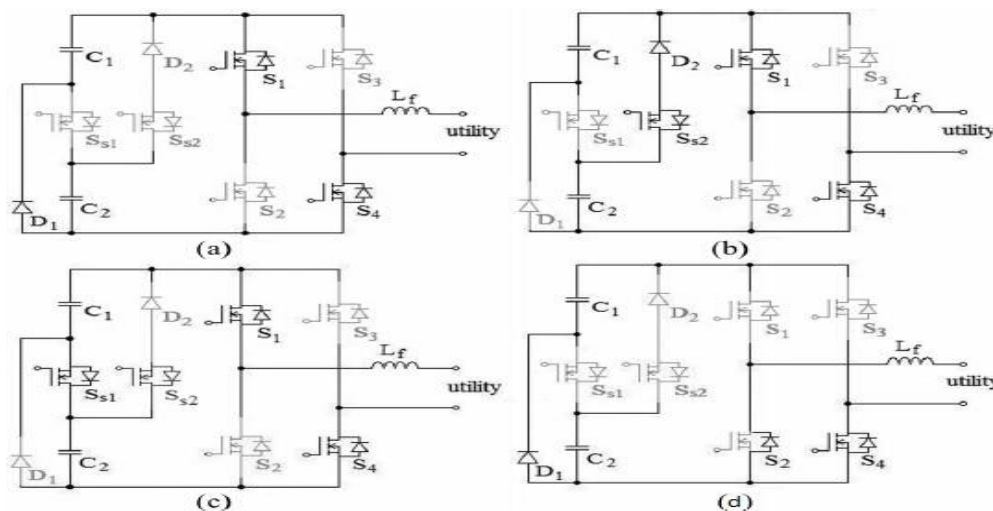


Fig. 4. Operation of the seven-level inverter in the positive half cycle, (a) mode 1, (b) mode 2, (c) mode 3, and (d) mode 4.

Consequently, in the positive half cycle, the yield voltage of the seven level inverter has four levels: V_{dc} , $2V_{dc}/3$, $V_{dc}/3$, and 0. Likewise, in the negative half cycle, the yield voltage of the seven level inverter has four levels: $-V_{dc}$, $-2V_{dc}/3$, $-V_{dc}/3$, and 0. The distinction is that S_2 and S_3 of the full-connect power converter. In synopsis, the yield voltage of the seven-level inverter has the voltage levels: V_{dc} , $2V_{dc}/3$, $V_{dc}/3$, 0, $-V_{dc}/3$, $-2V_{dc}/3$.

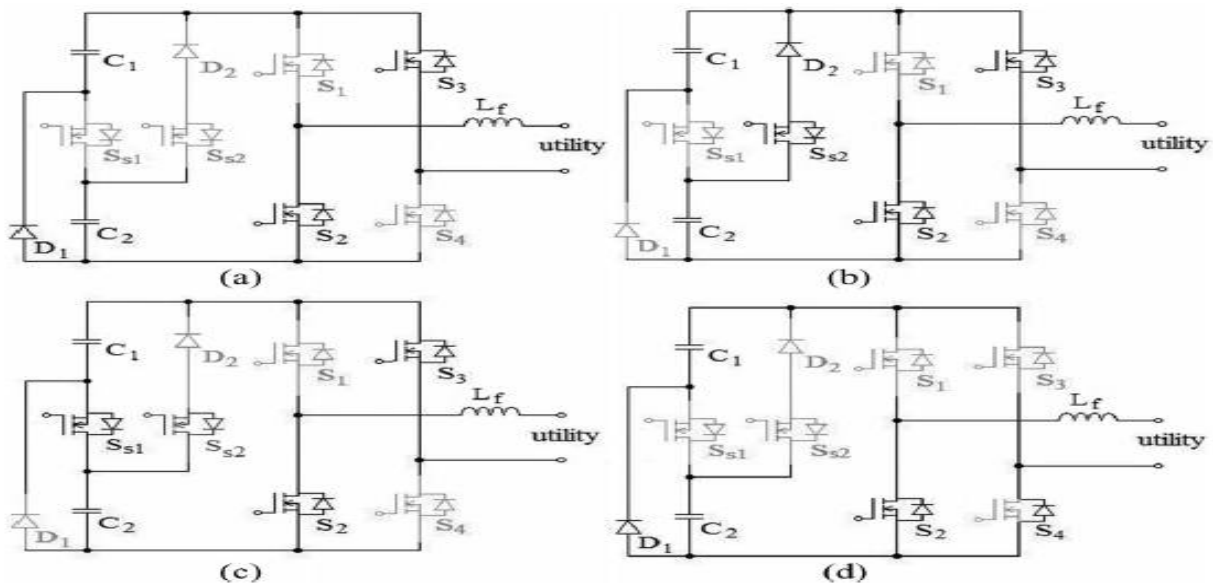


Fig. 5. Operation of seven-level inverter in the negative half cycle:(a) mode 5, (b) mode 6, (c) mode 7, and (d) mode 8.

III.CONTROL BLOCK

The seven-level inverter changes over the dc power into amazing air conditioning power and bolsters it into the utility and manages the voltages of capacitors C_1 and C_2 . The control object of the seven-level inverter is its yield current, which ought to be sinusoidal and in stage with the utility voltage. The dc–dc power converter supplies two free voltage sources with numerous connections and performs most extreme force point following (MPPT) so as to concentrate the greatest yield power from sun based cell array. A swell voltage with a recurrence that is twofold that of the utility shows up in the voltages of C_1 and C_2 , when the seven-level inverter encourages genuine force into the utility. The MPPT capacity is debased if the yield voltage of sun based cell cluster contains a swell voltage. Along these lines, the swell voltages in C_1 and C_2 must be obstructed by the dc–dc power converter to give enhanced MPPT. Appropriately, double control circles, an external voltage control circle and an inward current control circle, are utilized to control the dc–dc power converter. Subsequent to the yield voltages of the DC-DC power converter involves the voltages of C_1 and C_2 , which are controlled by the seven-level inverter, the external voltage control circle is utilized to direct the yield voltage of the sunlight based cell cluster. The inward current control circle controls the inductor current with the goal that it approaches a steady present and hinders the swell voltages in C_1 and C_2 .

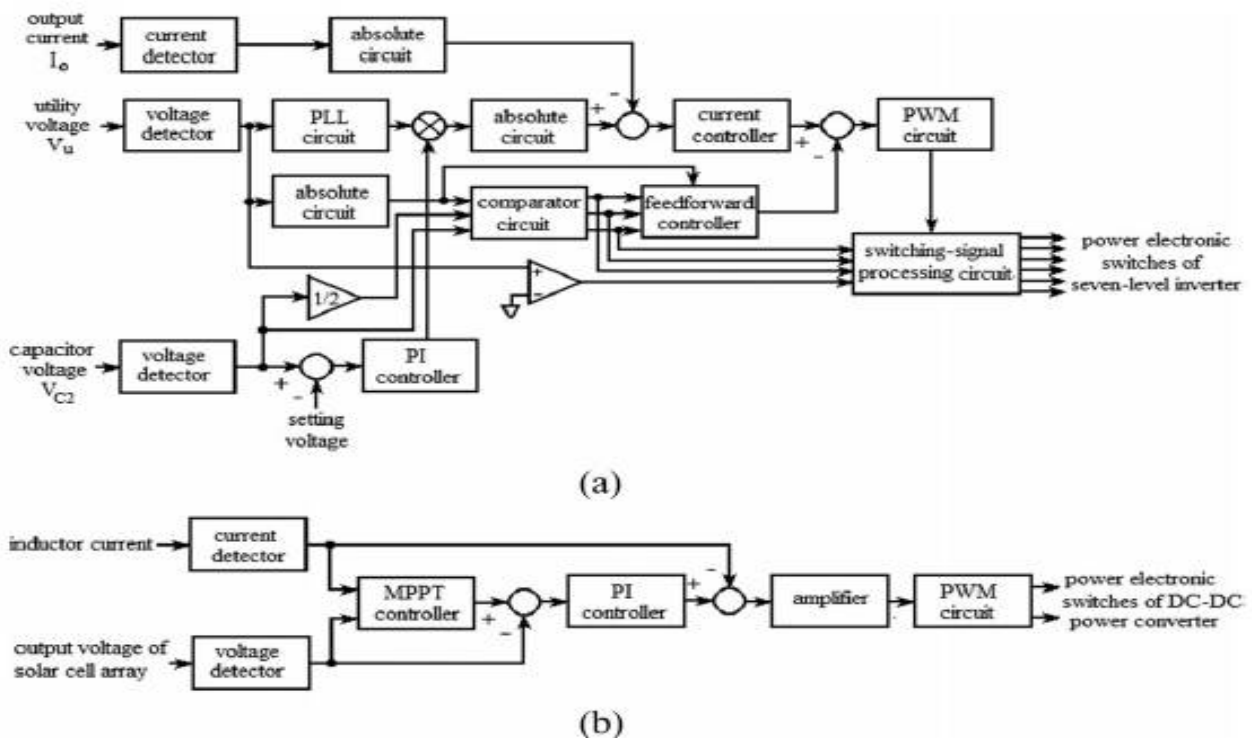


Fig.6 Control block: (a) seven-level inverter and (b) dc–dc power converter.

IV. SIMULATION RESULTS

Simulation for the solar power generation system with a seven-level inverter is done in matlab. Input voltage $V_{in}=70V$, switching frequency $f_s=15360Hz$, inductor values $L_o=1mh$, capacitor values $C_1=1\mu H$, $C_2=1\mu H$, filter inductor = $1.9mh$.

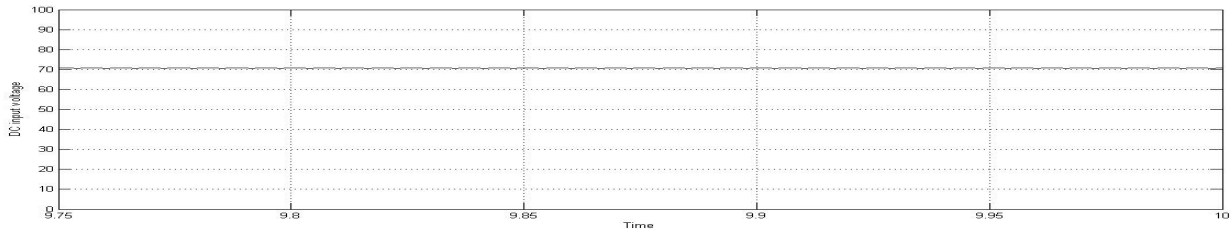


Fig.7.DC input voltage

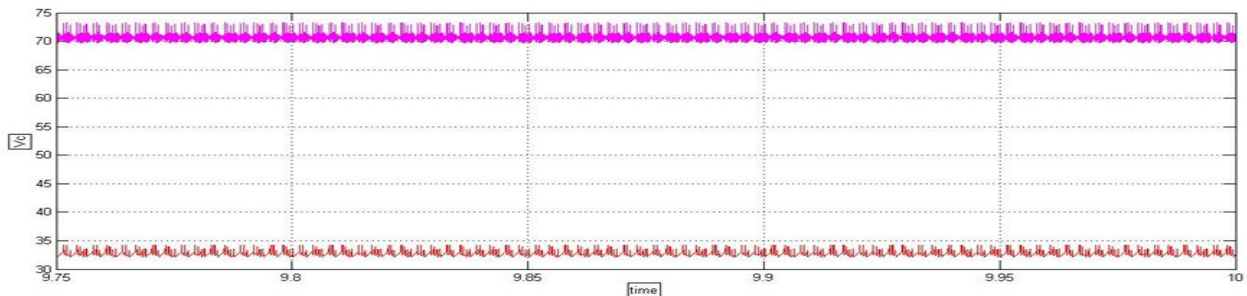


Fig.8 Voltages of capacitors C1 and C2.

Fig.8 shows that the voltages of capacitors C_1 and C_2 of the capacitor selection circuit have multiple relationships and are maintained at 32 and 71 V, respectively

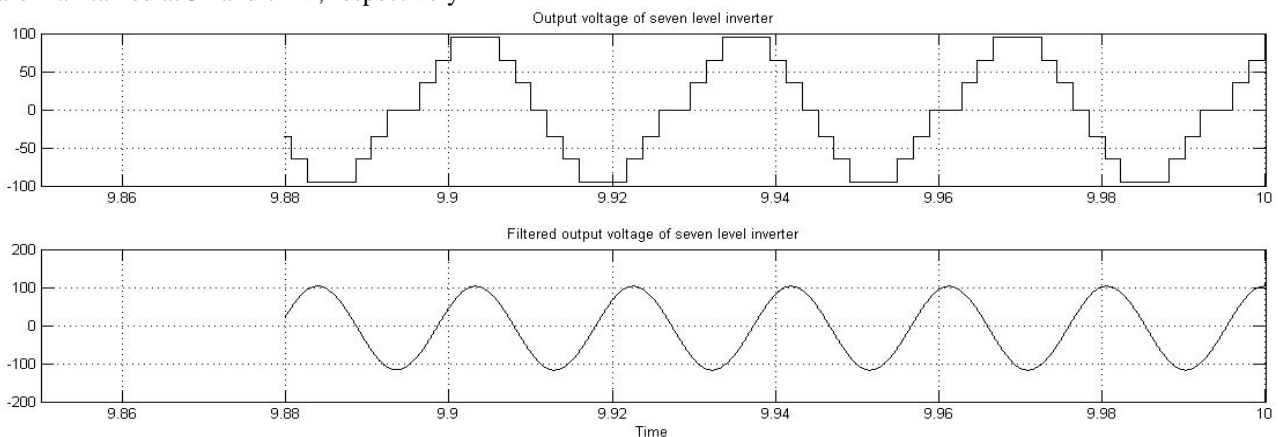


Fig. 9 output voltage of seven-level inverter.

Fig.9 shows the output voltage of seven-level inverter. It consists of seven voltage levels. This seven-level output voltage when passed through a filter, a pure sine wave will be obtained as shown in fig.9.

V. CONCLUSION

This paper proposes a solar power generation system to convert the dc energy generated by a solar cell array into ac energy that is fed into the utility. This reduces the switching power loss and improves the power efficiency. The proposed solar power generation system can effectively trace the maximum power of solar cell array.

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