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A Solar Power Generation System with a Seven-Level Inverter

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Abstract—This paper proposes a new solar power generation system, which is composed of a DC/DC power converter and a new seven-level inverter. The DC/DC power converter integrates a DC-DC boost converter and a transformer to convert 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. In this way, the proposed solar power generation system generates a sinusoidal output current that is in phase with the utility voltage and is fed into the utility. The salient features of the proposed seven-level inverter are that only six power electronic switches are used and only one power electronic switch is switched at high frequency at any time. A prototype is developed and tested to verify the performance of this proposed solar power generation system.

1.INTRODUCTION

The extensive use off fossil fuel resulted in the global problem of green house emissions. More over, as the supplies of fossil fuel are depleted in the future, they will become increasingly expensive. Thus 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. In particular, small-capacity distributed power generation systems using solar energy may be widely used in residential applications in the near future [1, 2].

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 feed st his AC power into the utility grid. An inverters necessary in the power conversion interface to convert the DC power to AC power[2-4]. 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 inter face is important to in sure there is no waste of the energy generated by the solar cell array. The active devices and passive devices in the inverter produce a power loss. The power losses due to active devices include both conduction losses and switching losses [5]..

This paper proposes an solar power generation system. The proposed solar power generation system 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. In this study, a prototype is developed and tested to verify the performance of the proposed solar power generation system.

1.Circuit Configuration

Figure 1 shows the configuration of the proposed solar power generation system. The proposed solar power generation system is composed of a solar cell array, a DC-DC power converter and a new seven-level inverter. The solar cell array is connected to the DC-DC power converter, and the DC-DC power converter is a boost converter that incorporates a transformer with a turn ratio of 2:1. The DC- DC power converter converts the output power of the solar cell array into two independent voltage sources with multiple

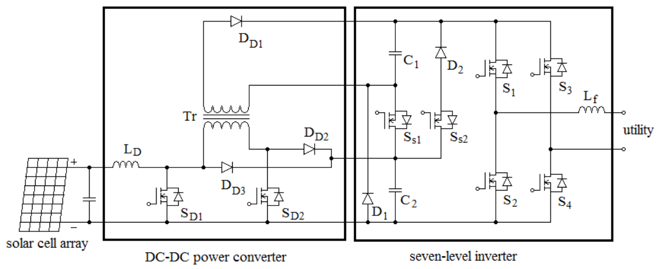


Fig.1 configuration of the proposed solar power generation system.

Generates a sinusoidal output current has is in phase with the utility voltage and is fed in to the utility, which produces a unity power factor. As can be seen, this news even-level inverter contains only six power electronics witches, so the power circuit is simplified.

I.I DC-DC Power Converter

As seen in Fig. 1, the DC-DC power converter incorporates a boost converter and a current-fed forward converter. The boost converter is composed of an inductor, LD, a power electronic switch, SD1, and a diode, DD3. The boost converter charges capacitor C2 of the seven-level inverter. The current-fed forward converter is composed of an inductor, LD, power electronic switches, SD1 and SD2, a transformer and diodes, DD1 and DD2. The current-fed forwardconverterchargescapacitorC1oftheseven-level inverter. The inductor, LD, and the power electronic switch, SD1, of the current-fed forward converter are also used in the boost converter.

Figure 2(a) shows the operating circuit of the DC-DC power converter when SD1 is turned on. The solar cell array suppliesenergytotheinductorLD.WhenSD1isturnedoff andSD2 is turned on, its operating circuit is showninFig.2(b). Accordingly, capacitor C1 is connected to capacitor C2 in parallel through the transformer, so the energy of inductor L D and the solar cell array charge capacitorC2throughDD3andchargecapacitorC1throughthetransformer and DD1duringtheoffstateof SD1.Sincecapacitors C1and C2are charge din parallel by using the transformer, the voltageratioofcapacitorsC1andC2isthesameastheturnratio(2:1)ofthetransformer.Therefore,thevoltagesof C1 and C2 have multiple relationships. The boost converter is operated in the continuous conduction mode (CCM). The voltage of C2 can be represented as: $V_{c2}=(1/1-D)V_s$

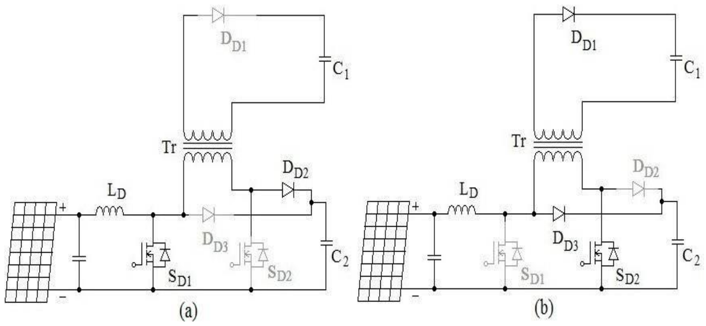
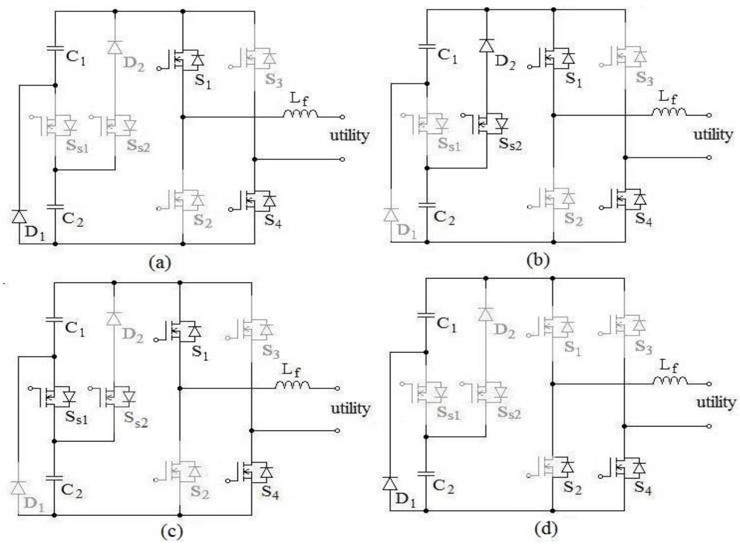


Fig.2 & 3 operation of DC-DC power converter,(2)SD1 is on,(3) SD1 is off.

1.2 Seven-Level Inverter

AsseeninFig.1,the seven-levelinverteriscomposedofacapacitorselectioncircuitandafull-bridge power converter, which are connected in cascade. Operation of the seven-level inverter can be divided into the positive half cycle and the negative half cycle of the utility. For ease of analysis, the power electronic switches and diodes are assumed to be ideal, while the voltages of both capacitors C1 and C2 in the capacitor selection circuit are constant and equal to Vdc/3 and 2Vdc/3, respectively. Since the output current of the solar power generation system will be controlled to be sinusoidal and in phase with the utility voltage, the output current of the seven-level inverter is also 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 divided into four modes, as shown in Fig.3.



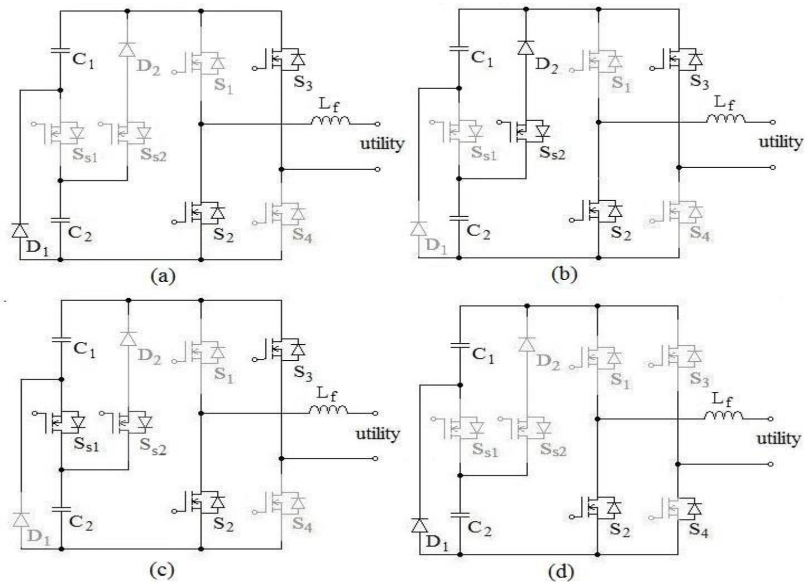


Fig.4 operation of seven-level invert

Results

To verify the performance of the proposed solar power generation system, a proto type was developed with a controller based on the DSP chipTMS320F28035. The power rating of the proto type is 500W, and the proto type was used for a single-phase utility with 110V and 60Hz. Table II shows the main parameters of the prototype. Figures 5 and 6 show the experimental results for the seven-level inverter when the output power of solar power generation system is 500W. Figure 6 shows the experimental results for the AC side of the seven-level inverter. Figure5 (b) shows that the output voltage of the seven-level inverter has seven voltage levels. The output current of the seven-level inverter, shown inFig.6(c),is sinusoidal and in phase with the utility voltage, which means that the grid-connected power conversion interface feeds a pure real power to the utility. The total harmonic distortion (THD) of the output current of the seven-level inverter is 3.6%. Figure 8 shows the experimental results for the DC side of the seven-level inverter. Figures 6(b) and(c) show that the voltages of capacitors C2 and C1of the capacitor selection circuit have multiple relationships and are maintained at 60Vand120V,respectively.Figure 10(d) shows that the output voltage of the capacitor selection circuit has three voltage levels (60V, 120V and 180V). Figure 11 shows the experimental results for the DC-DC power converter. Figures 7(b) and (c) show that the ripple voltages in capacitors C1 and C2 of the capacitor selection circuit are evident.

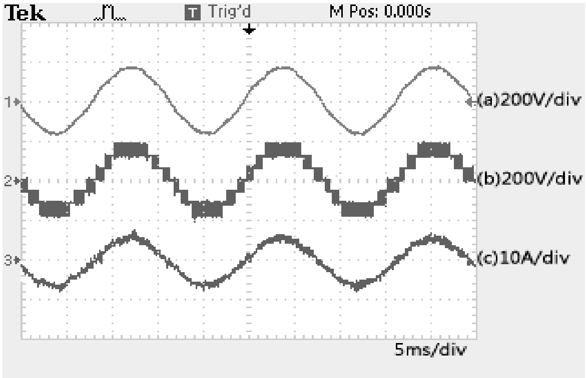


Fig.5 experimentalresultsfortheACsideoftheseven-levelinverter,(a)utilityvoltage,(b)outputvoltageofseven-levelinverter,(c)outputcurrentofseven-levelinverter.

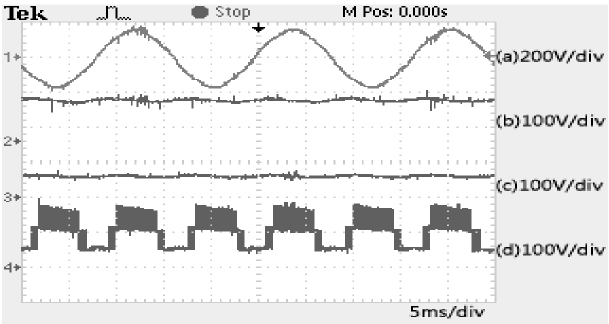


Fig.6 experimental results for the DC side of the seven-level inverter,(a)utility voltage,(b) voltageofcapacitorC2,(c)voltage of capacitor C1,(d) output voltage of capacitor selection circuit.

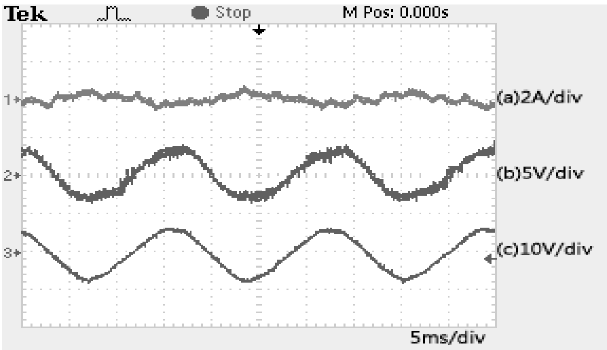


Fig.7.experimental results of the DC-DC power converter,(a) ripple current of

inductor,(b)ripple voltage of capacitor C2, (c) ripple voltage of capacitor C1.

Conclusion

This paper proposes a solar power generation system to convert the DC energy generated by a solar cell array in to AC energy that is fed in to the utility. The proposed solar power generation system is composed of a DC/DC power converter and a seven-level inverter. The seven-level inverter contains only six power electronic switches, which simplifies the circuit configuration. Furthermore, only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage. This reduces the switching power loss and improves the power efficiency. The voltages

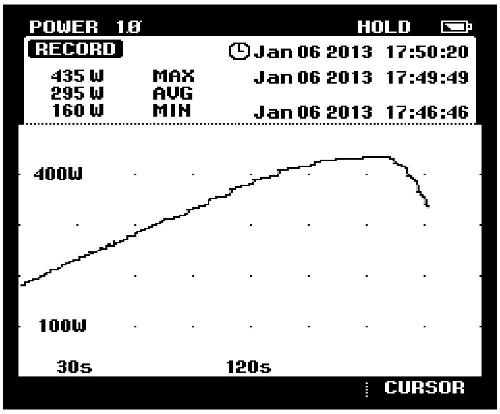


Fig.8 output power scan of the solar cell array.

of the two DC capacitors in the proposed seven-level inverter are balanced automatically, so the control circuit is simplified. Experimental results show that the proposed solar power generation system generates a seven-level output voltage and outputs a sinusoidal current that is in phase with the utility voltage, yielding a power factor of unity. In addition, the proposed solar power generation system can effectively trace the maximum power of solar cell array.

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