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Levels of Inverter by Using Solar Array Generation System

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ABSTRACT:

The New solar generation system which is composed of a dc/dc power converter and a novel seven-level inverter. Dc/dc converter integrates a dc–dc boost converter and a transformer to convert the output voltage of the solar PV into two independent voltage sources with multiple connections. This new seven-level inverter is configured by a capacitor selection circuit and a full-bridge power converter, by using cascading connection. The capacitor selection circuit converts the duel output voltage of dc–dc converter into a three-level dc voltage, and full-bridge converter converts this three-level dc voltage into a seven-level ac voltage. By the above procedure 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.

Exciting concept:

Multilevel inverter topologies include the diode clamped, the flying-capacitor, and the cascade H-bridge types. Diode-clamped and flying capacitor multilevel inverters use capacitors to develop several voltage levels. Since it is hard process to control the voltage of capacitors. Since it is difficult to create an identical voltage technology in both the diode-clamped and the flying capacitor, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. A 1-phase 7-level inverter, twelve power electronic switches are needed in both the diode-clamped and the flying-capacitor topologies.

Identical voltage converter is used in the cascade H-bridge multilevel inverter to allow implementing additional attached circuit, so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels. Duel H-bridge inverters with a dc bus voltage of multiple relationships can be connected in cascade to produce a 1-phase 7-level inverter and eight power electronic switches are used. Various novel topologies for sevenlevel inverters have been proposed. A single-phase seven-level grid-connected inverter has been developed for a photovoltaic system. This seven-level grid-connected inverter contains six power electronic switches. Three dc capacitors are used to construct the three voltage levels, which results in that balancing the voltages of the capacitors is more complex.

Proposed Concept:

Multi-level inverter converter, configured by a level generation part and a polarity generation part, is proposed. There, only power electronic switches of the level generation part switch in high frequency. A modular multilevel inverter with a new modulation method is applied to the photovoltaic grid-connected generator. The modular multilevel inverter is similar to the cascade H-bridge type. For this, a new modulation method is proposed to achieve dynamic capacitor voltage balance. Overcome the problem of partial shading of individual photovoltaic sources that are connected in series. The dc bus of a full-bridge inverter is configured by several individual dc blocks, where each dc block is composed of a solar cell, a power electronic switch, and a diode. Controlling the power electronics of the dc blocks will result in a multilevel dc-link voltage to supply a full-bridge

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inverter and to simultaneously overcome the problems of partial shading of individual photovoltaic sources

Introduction:

The use of fuels has resulted in the global problem of greenhouse effect. As the supplies of fuels are depleted in the future, they will become increasingly expensive. Since 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. 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 insure that 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. Conduction loss results from the use of active devices, while the switching loss is proportional to the voltage and the current changes for each switching and switching frequency. A filter inductor is used to process the switching harmonics of an inverter, so the power loss is proportional to the amount of switching harmonics. The voltage change in each switching operation for a multilevel inverter is reduced in order to improve its power conversion efficiency and the switching stress of the active devices. The amount of switching harmonics is also attenuated, so the power loss caused by the filter inductor is also reduced.

PROPOSED CONCEPT CONFIGURATION:

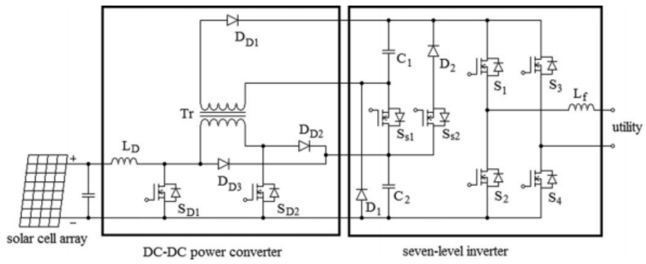

Fig. 1.Configuration of the proposed solar power generation system.

Above figure 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. The dc–dc power converter converts the output power of the solar cell array into two independent voltage sources with multiple relationships, which are supplied to the seven-level inverter.

The full-bridge power converter further converts this three-level dc voltage to a seven-level ac voltage that is synchronized with the utility 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, which produces a unity power factor. As can be seen, this new seven-level inverter contains only six power electronic switches, so the power circuit is simplified.

POWER CONVERTER:

DC-DC type power converter:

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 forward converter charges

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capacitor C1 of the seven-level inverter. The inductor LD and the power electronic switch SD1 of the current-fed forward converter are also used in the boost converter. Fig. 2(a) shows the operating circuit of the dc–dc power converter when SD1 is turned ON. The solar cell array supplies energy to the inductor LD . When SD1 is turned OFF and SD2 is turned ON, its operating circuit is shown in Fig. 2(b). Accordingly, capacitor C1 is connected to capacitor C2 in parallel through the transformer, so the energy of inductor LD and the solar cell array charge capacitor C2 through DD3 and charge capacitor C1 through the transformer and DD1 during the offstate of SD1. The boost converter is operated in the continuous conduction mode (CCM). The voltage of C2 can be represented as

$$V_{c2} = \frac{1}{1 - D} V_s \qquad (1)$$

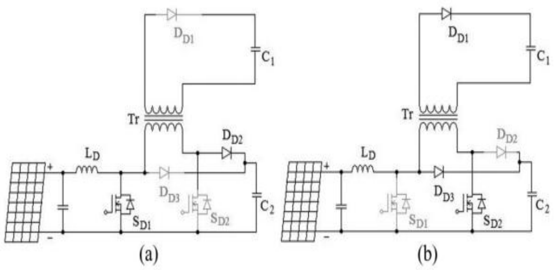

Fig.2. Operation of dc–dc power converter: (a) SD 1 is on and (b) SD 1 is off.

WORKING PRINCIPLE:

- **SEVEN-LEVEL INVERTER:**

As seen in Fig. 1, the seven-level inverter is composed of a capacitor selection circuit and a full-bridge power converter, which are connected in cascade. The operation of the sevenlevel 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.

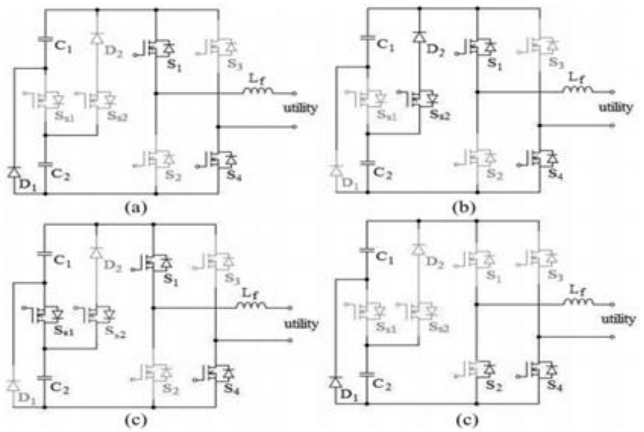

Fig. 3. Operation of the seven-level inverter in the positive half cycle,
(a) mode 1, (b) mode 2, (c) mode 3, and (d) mode 4.

Mode of operation:

Stage 1: The operation of mode 1 is shown in Fig. 3(a). Both SS1 and SS2 of the capacitor selection circuit are OFF, so C1 is discharged through D1 and the output voltage of the capacitor selection circuit is Vdc /3. S1 and S4 of the full-bridge power converter are ON. 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 Vdc /3.

Stage 2: The operation of mode 2 is shown in Fig. 3(b). In the capacitor selection circuit, SS1 is OFF and SS2 is ON, so C2 is discharged through SS2 and D2 and the output voltage of the capacitor selection circuit is 2Vdc /3. S1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is 2Vdc /3.

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Stage 3: The operation of mode 3 is shown in Fig. 3(c). In the capacitor selection circuit, SS1 is ON. Since D2 has a reverse bias when SS1 is ON, the state of SS2 cannot affect the current flow. Therefore, SS2 may be ON or OFF, to avoiding switching of SS2 . Both C1 and C2 are discharged in series and the output voltage of the capacitor selection circuit is Vdc . S1 and S4 of the full-bridge power converter are ON. At this point, the output voltage of the seven-level inverter is Vdc .

Stage 4: The operation of mode 4 is shown in Fig. 3(d). Both SS1 and SS2 of the capacitor selection circuit are OFF. The output voltage of the capacitor selection circuit is Vdc /3. Only S4 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 S2 to be switched ON for continuous conduction of the filter inductor current. At this point, the output voltage of the sevenlevel inverter is zero.

Control Topologies:

The 7-level inverter is controlled by the currentmode. And PWM is use to generate the control signals for the switches. The voltage of the seven-level inverter must be switched in duel levels. One level of the output voltage is higher than the utility voltage in order to increase the filter inductor current, and the other level of the output voltage is lower than the utility voltage, in order to decrease the filter inductor current. In this way, the output current of the seven-level inverter can be controlled to trace a reference current. Accordingly, the output voltage of the seven-level inverter must be changed in accordance with the utility voltage.In the positive half cycle, when the utility voltage is smaller than Vdc /3, the seven-level inverter must be switched between modes 1 and 4 to output a voltage of Vdc /3 or 0. Within this voltage range, S1 is switched in PWM. The duty ratio d of S1 can be represented as

$$d = v_m / V_{\rm tri}$$

wherev m and Vtri are the modulation signal and the amplitude of carrier signal in the PWM circuit, respectively. The output voltage of the seven-level inverter can be written as

$$v_o = d \cdot V_{\rm dc}/3 = k_{\rm pwm} v_m \qquad (4)$$

Where kpwm is the gain of inverter, which can be written as

$$k_{\rm pwm} = V_{\rm dc}/3V_{\rm tri}. \qquad (5)$$

Fig. 5(a) shows the simplified model for the seven-level inverter when the utility voltage is smaller than Vdc /3. The closed loop transfer function can be derived as

$$I_o = \frac{k_{\rm pwm} G_c / L_f}{s + k_i k_{\rm pwm} G_c / L_f} I_o^* - \frac{1/L_f}{s + k_i k_{\rm pwm} G_c / L_f} V_u \qquad (6)$$

Where Gc is the current controller and ki is the gain of the current detector.

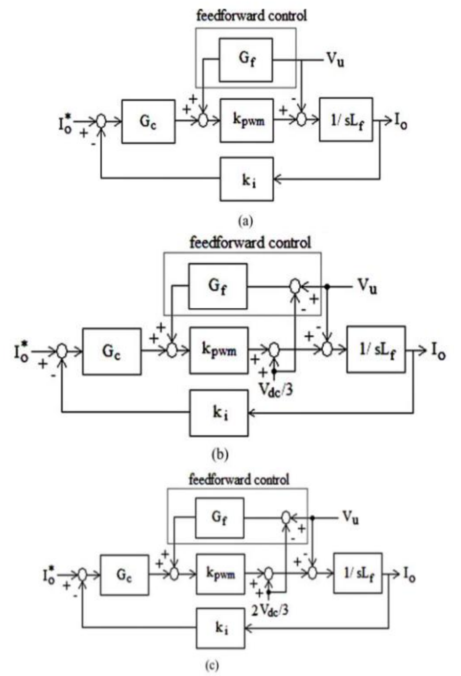

Fig. 5.Model of the seven-level inverter under different range of utility voltage, (a) in the range of

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smaller than Vdc /3, (b) in the range of (Vdc /3, 2Vdc /3), (c) in the range of higher than 2Vdc /3.

CONTROL BLOCK:

The proposed solar power generation system consists of a dc– dc power converter and a seven-level inverter. The seven-level inverter converts the dc power into high quality ac power and feeds it into the utility and regulates the voltages of capacitors C1 and C2 . The dc–dc power converter supplies two independent voltage sources with multiple relationships and performs maximum power point tracking (MPPT) in order to extract the maximum output power from the solar cell array.

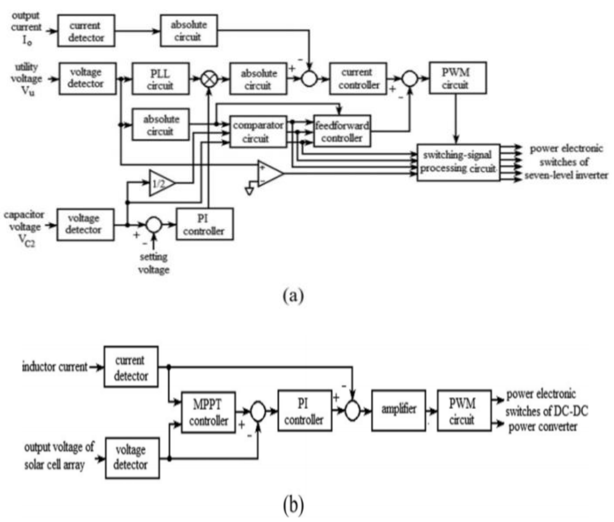

Fig. 8. Control block: (a) seven-level inverter and (b) dc–dc power converter.

A. Seven-Level Inverter:

Fig . 8(a) shows the control block diagram for the seven-level inverter. The control object of the seven-level inverter is its output current, which should be sinusoidal and in phase with the utility voltage. The utility voltage is detected by a voltage detector, and then sent to a phase-lock loop (PLL) circuit in order to generate a sinusoidal signal with unity amplitude. The voltage of capacitor C2 is detected and then compared with a setting voltage. The compared result is sent to a PI controller. Then, the outputs of the PLL circuit and the PI controller are sent to a multiplier to produce the reference signal, while the output current of the seven-level inverter is detected by a current detector.

B. DC–DC Power Converter:

Below figure shows the control block diagram for the dc–dc power converter. The input for the DC-DC power converter is the output of the solar cell array. A ripple voltage with a frequency that is double that of the utility appears in the voltages of C1 and C2, when the seven-level inverter feeds real power into the utility. The MPPT function is degraded if the output voltage of solar cell array contains a ripple voltage. Therefore, the ripple voltages in C1 and C2 must be blocked by the dc–dc power converter to provide improved MPPT. Accordingly, dual control loops, an outer voltage control loop and an inner current control loop, are used to control the dc–dc power converter. Since the output voltages of the DC-DC power converter comprises the voltages of C1 and C2, which are controlled by the seven-level inverter, the outer voltage control loop is used to regulate the output voltage of the solar cell array. The inner current control loop controls the inductor current so that it approaches a constant current and blocks the ripple voltages in C1 and C2 . The perturbation and observation method is used to provide MPPT [24]. The output voltage of the solar cell array and the inductor current are detected and sent to a MPPT controller to determine the desired output voltage for the solar cell array

EXPERIMENTAL RESULTS:

To verify the performance of the proposed solar power generation system, a prototype was developed with a controller based on the DSP chip TMS320F28035. The power rating of the prototype is 500 W, and the prototype was used for a single-phase utility with 110 V and 60 Hz

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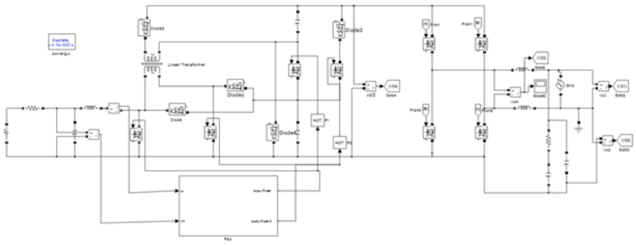
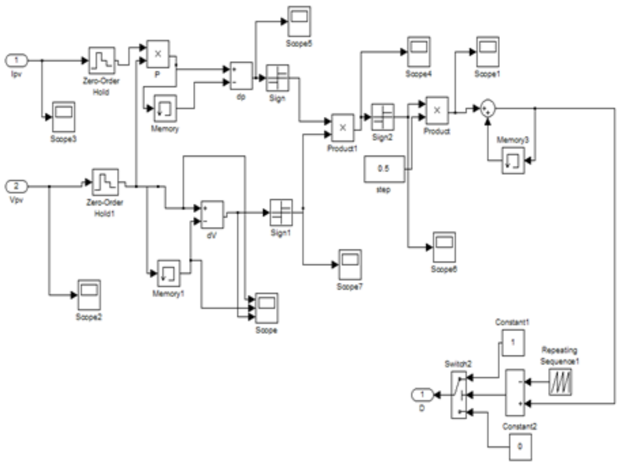
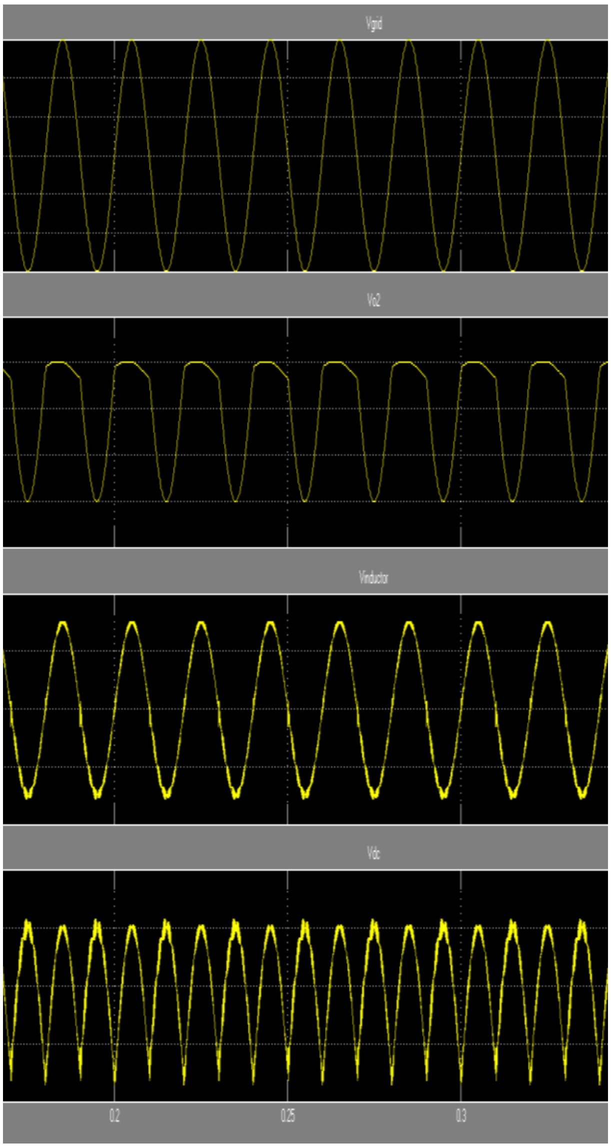
MATLAB MODEL:

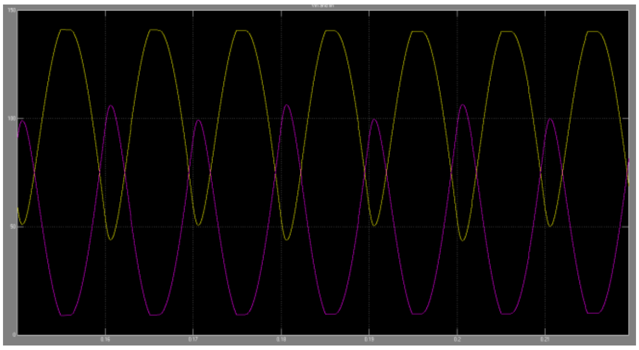


P&O MODEL:



OUTPUT WAVEFORMS:





Input voltage and current

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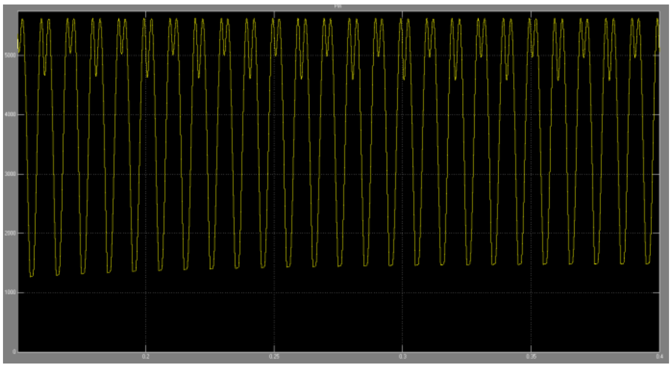
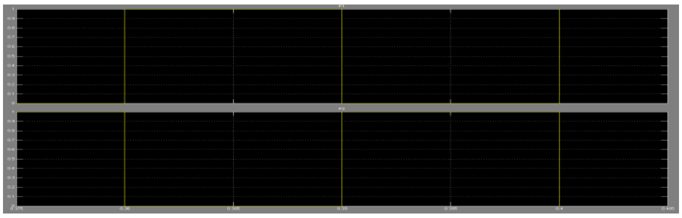


Input power



Pulses P1&p2

CONCLUSION:

The solar power generation system to convert the dc energy generated by a solar cell array into AC energy that is fed into the utility. 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 of the two dc capacitors in the proposed seven-level inverter are balanced automatically, so the control circuit is simplified. In addition, the proposed solar power generation system can effectively trace the maximum power of solar cell array.

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