A MULTILEVEL INVERTER TOPOLOGY FOR RENEWABLE POWER GENERATION

S.Karthick[1] | K.Sanjeevikumar[2] | T.Rajkumar[3]

[1](Assistant professor, The Kavery college of Engineering, Salem, Tamilnadu)
[2](Assistant professor, The Kavery college of Engineering, Salem, Tamilnadu)
[3](Assistant professor, The Kavery college of Engineering, Salem, Tamilnadu)

***Abstract*—*In this paper, a new multi-level inverter topology is developed and applied for injecting the real power of the renewable power into the grid to reduce the switching power loss, harmonic distortion caused by the switching operation of power electronic devices. Here this multi-level inverter configures with input dc capacitors, a dual-buck converter, a full-bridge inverter, and a filter. The input to the dual-buck converter is dc capacitor voltage sources. The power electronic switches of the full-bridge inverter are switched in low frequency synchronous with the utility voltage to convert the output voltage of the dual-buck converter to a multi-level ac voltage. The output current of the multi-level inverter is controlled to generate a sinusoidal current in phase with the utility voltage to inject into the grid. The five-level inverter topologies are developed to verify the performance of the developed renewable power generation system and however the THD of both five-level and nine-level inverter topologies are analyzed. The simulation results show that the developed renewable power generation system reaches the expected performance.*

***Keywords*—Multilevel inverters, Total harmonic distortion, power electronics**

1. INTRODUCTION

The extensive use of fossil fuels has resulted in the global problem of greenhouse emissions. Moreover, as the supplies of fossil fuels 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. Generally the conventional single-phase inverter topologies interfacing to grid connection include half-bridge and full bridge[1],[3],[4]. All power electronic a full-bridge inverter and a filter. In the below sections five level implementation is explained. The same implementation will be provided for nine level also, but in this actual circuit configuration, needs additional two capacitors and two switches in dual buck converter switches operate in high switching frequency in both half-bridge and full bridge inverters. The switching operation will result in switching loss. The loss of power electronic switch includes the switching loss and the conduction loss. The conduction loss depends on the handling power of power electronic switch. The switching loss is proportional to the switching frequency, voltage jump of each switching, and the current of the power electronic switches. The power efficiency can be advanced if the switching loss of the dc–ac inverter is reduced. The popular modulation strategies or the full-bridge inverter are unipolar modulation and bipolar modulation[4],[7]. Multilevel inverter can effectively reduce the voltage jump of each switching operation to reduce the switching loss and increase power efficiency. However, interest in the multilevel inverter has become more popular due to its advantages of better power efficiency, lower switching harmonics. The conventional single-phase multilevel inverter topologies further classified as the diode-clamped[2], the flying capacitor, and the cascade H-bridge types as shown in Fig. 1(a),(b),(c). Thus, both the performance and complexity should be considered in designing the multilevel inverter[8]-[9] .However, interest in the multilevel inverter has become more popular due to its advantages of better power efficiency, lower switching harmonics. In this paper, a five-level inverter and nine-level inverter are developed and applied for injecting the real power of the renewable power into the grid. This developed multi-level inverter topologies are basically configured by an input dc capacitors, a dual-buck converter, a full-bridge inverter, and a filter. In this paper five-level inverter is developed that configures an two dc capacitors, a dual buck converter and finally both the results of five and nine level inverter are as shown in the simulation results. Firstly the circuit configuration of five-level inverter which is applied to photovoltaic power generation system as shown.

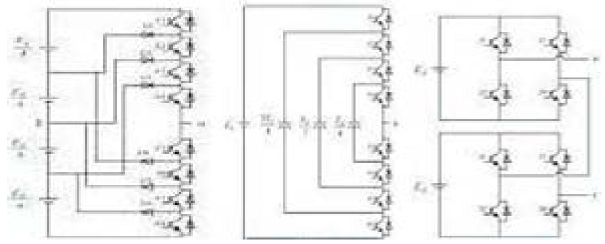

Fig 1: Circuit configuration of conventional single phase five-level inverter.(a) Diode clamped. (b) Flying capacitor.(c) Cascade H-bridge.

2. CIRCUIT CONFIGURATION

The actual circuit configuration of the five-level inverter that applied to renewable power generation system shown in fig2. As can be seen, it is configured by a solar cell array, a dc–dc converter, a five-level inverter, two switches, and controller. Here the Switches SW1 and SW2 are placed between between the five-level inverter and the utility, and these are used to disconnect the photovoltaic power generation system from the utility when islanding operation occurs. The load is placed between switches SW1 and SW2. The five-level inverter is being configured by two dc capacitors, a dual buck converter, a full-bridge inverter, and a filter. The dual-buck converter is configured by two buck converters. The two dc capacitors acts as energy buffers between the dc–dc converter and the five-level inverter. The output of the dual-buck converter is connected to the full-bridge inverter to convert the dc voltage to ac voltage. An inductor is placed at the output of the full bridge inverter to form as a filter inductor for filtering out the high-frequency switching harmonic generated by the dual-buck converter.

3. FIVE- LEVEL INVERTER OPERATION

The five-level inverter operation can be classified into eight modes. Modes 1–4 are for the positive half-cycle, and modes 5–8 are for the negative half-cycle as shown in fig3.

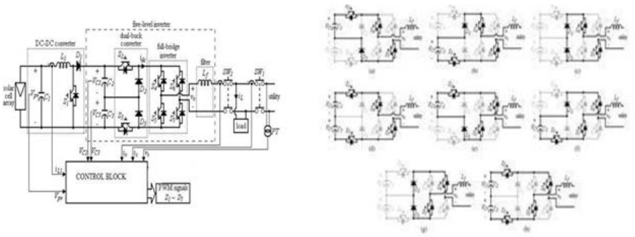

Fig.3: Operation modes of the five-level inverter. (a) Mode 1. (b) Mode 2. (c) Mode 3. (d) Mode 4. (e) Mode 5.(f) Mode 6. (g) Mode 7. (h) Mode 8.

As seen in Fig. 3(a)–(d), the power electronic switches S4 and S7 are in the ON state, and the power electronic switches S5 and S6 are in the OFF state during the positive half-cycle. On the contrary, the power electronic switches S4 and S7 are in the OFF state, and the power electronic switches S5 and S6 are in the ON state during the negative half-cycle. At mode 1, mode2, the output voltage of dual buck converter and five-level inverter are Vdc/2 and at mode3 output voltages of the dual buck converter and five-level inverter are 0, at mode4 output voltages of the dual-buck converter and five-level inverter are Vdc during positive half cycle. Modes 5–8 are the operation modes for the negative half cycle. The operations of the dual-buck converter under modes 5–8 are similar to that under modes 1–4, and the dual-buck converter can also generate three voltage levels Vdc/2, Vdc/2, 0, and Vdc, respectively.

3.1 VOLTAGE BALANCING OF FIVE-LEVEL INVERTER

Voltage balance of dc capacitors is very crucial in controlling the multilevel inverter. The voltage balance of dc capacitor voltages VC2 and VC3 can be controlled by the power electronic switches S2 and S3 easily. When the absolute of the utility voltage is smaller than Vdc/2, one power electronic switch either S2 or S3 is switched in highfrequency and the other is still in the OFF state.When the absolute of the utility voltage is higher than Vdc/2, one power electronic switch either S2 or S3 is switched in high frequency and the other is still in the ON state

TABLE 1: ON/OFF STATE OF S2 AND S3.

		|Vs|<|Vdc/2|	|Vs|>Vdc/2
Vc2>Vc3	S2	PWM	ON
	S3	OFF	PWM
Vc2> Vc3	S2	OFF	PWM
	S3	PWM	ON

4. CONTROL BLOCK DIAGRAM

The developed photovoltaic power generation system consists of a dc–dc power converter and the five-level inverter Fig.4(a) shows the control block diagram of five-level inverter. In the operation of the five-level inverter, the dc bus voltage must be regulated to be larger than the peak voltage of the utility and the dc capacitor voltages of C2 and C3 must be controlled to be equal. Besides, the five-level inverter must generate a sinusoidal current in phase with the utility voltage to be injected into the utility. The control block diagram of dc-dc converter is shown in fig 4(b). The input of dc-dc converter is the output of solar cell array . The perturbation and observation method is adopted to obtain the function of MPPT, and it is incorporated into the controller of the dc– dc converter. The output of the MPPT controller is the desired output voltage of the solar cell array, and it is the reference voltage of the outer voltage control loop. The output voltage of the solar cell array is perturbed first, and then the output power variation of the solar cell array is observed to determine the next perturbation for the output voltage of the of the solar cell array and the inductor current. Therefore, 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 of the solar cell array. The detected output voltage and desired output voltage of the solar cell array are sent to a sub tractor, and the subtracted solar cell array. The output power of the solar cell array is calculated from the product of the output voltage result is sent to a P-I controller. The output of the amplifier is sent to the PWM circuit. The output signal of the PWM circuit is the driving signal for the power electronic switch of the dc–dc converter.

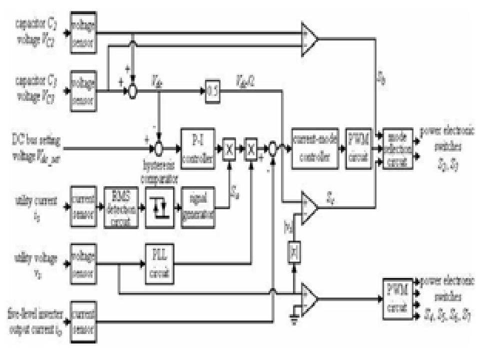

fig4(a): control block of five-level inverter

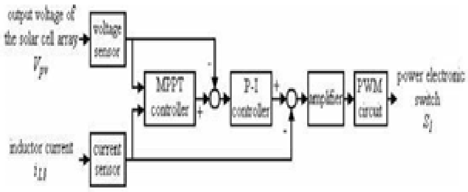

fig4(b): control block of dc-dc converter

TABLE 2: COMPARISION OF FIVE-LEVEL INVERTERS

	Cascaded H-bridge	Flying capacitor	Diode clamped	Developed inverter
Power electronic switches	8	8	8	6
capacitors	2	4	2	2
Voltage balance of capacitors	Hard	Hard	hard	Easy
High frequency switches	8	8	8	2

5. SIMULATION RESULTS

To check the performance of the photovoltaic power generation system using the five-level and nine level inverter, MATLAB/SIMULINK is used.

The main parameters of the simulations are listed in Table II. The solar cell array consists of two strings, and each string contains eight solar modules connected in series. The capacity of solar cell array is 1.2 kW. The environmental temperature and radiation levels are 30.7o C and 922 W/m2 respectively .The temperature of solar module 52.3oC The maximum power output of solar cell array is maintained about 830W. fig5: voltage and current characteristics of the solar cell array is shown below

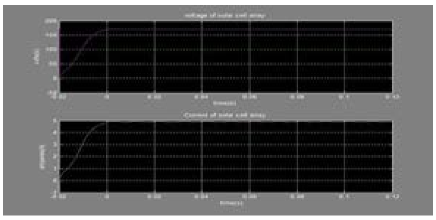

Fig5: voltage and current characteristics of the solar cell array

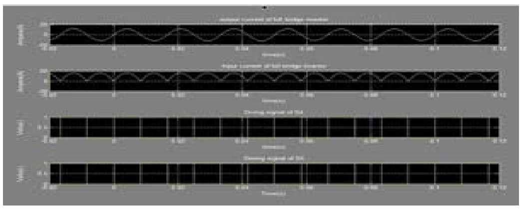

Fig 6.Simulation results for full-bridge inverter of the five- level inverter. (a) Output current of the full-bridge inverter io. (b) Input current of the full bridge inverter idc . (c) Driver signal of S4 . (d) Driver signal of S5

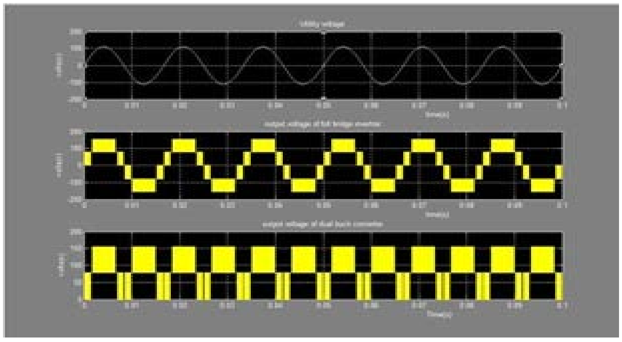

Fig7: Simulation results of five-level inverter (a) Utility voltage (b) output voltage of five -level inverter (c) output voltage of dual buck converter

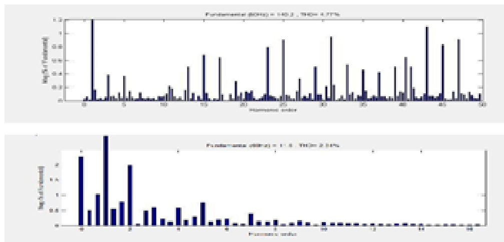

Fig 9: Harmonic distortion of (a) Utility voltage (b) output current of five-level inverter

The output power of the solar cell array in the developed photovoltaic power generation system is about 830 W. Therefore, the developed photovoltaic power generation system can track the maximum power point of the solar cell array effectively As seen in Fig. 6(b), the output current of the five-level inverter is sinusoidal and in phase with the utility voltage. The total harmonic distortion (THD%) of the utility voltage and the output current of the five-level inverter are 4.77% and 2.48%,their voltage is about 85 V, respectively. Therefore, the dc bus voltage is regulated at 170 V. This verifies the five-level inverter can perform the functions of converting solar power to ac power with unity power factor, low THD%, and balancing two dc capacitor voltages effectively voltage ripple at dc capacitors C2 and C3 is about 7 V. As seen in. Fig.6 shows the simulation results for the full-bridge inverter of the five-level inverter.

As can be seen, the input current idc of the full-bridge inverter shown in Fig.8(b) is the absolute of the output current of the full - bridge inverter shown in Fig. 6(a). As seen in Fig. 6(c) and (d), the switch frequency of the power electronic switches S4 and S5 is 60 Hz. This verifies the power electronic switches of the full-bridge inverter are switched in low frequency, and the full-bridge inverter can convert the dc power into ac power by commutating. The above figures shows the simulation voltage of the five-level inverter. As seen in Fig.7(c),the dual-buck converter output a dc voltage with three levels Vdc, Vdc/2, and 0.Fig.7(b) shows the output voltage of the dual-buck converter is further converted to an ac voltage with five voltage levels Vdc, Vdc/2, 0, −Vdc/v2, and −Vdc by the full-bridge inverter. The voltage variation of each level is Vdc/2.this verified that the five-level inverter can generate a five-level output ac voltage according to the utility voltage and only the power electronic switches of the dual-buck converter is switched in high frequency.

Fig.8 shows the simulation results for the developed photovoltaic power generation .system under the distorted utility voltage. As seen in Fig. 8(a), the utility voltage is distorted. As seen in Fig. 8(b), the output current of the five-level inverter is still close to sinusoidal, and its THD% is only 5.6% and the power factor is 0.99. The total harmonic distortion (THD%) of the utility voltage and theutput current of the five-level inverter are 4.73% and 2.48%, respectively which are shown in fig 9.

6. CONCLUSION

A photovoltaic power generation system with a five-level inverter is developed in this thesis. The five level topology can perform the functions of regulating the dc bus voltage, converting solar power to ac power with sinusoidal current and in phase with the utility voltage, balancing the two dc capacitor voltages. The Simulation results verify the developed photovoltaic power generation system, and the five-level and nine level inverter achieves the expected performance .The total harmonic distortion of both topology are analyzed and compare the performance of five level inverter topology

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