SEVEN LEVEL INVERTER FOR RENEWABLE POWER GENERATION

MR. AMAN SINGH [1], MR. NIKHIL SHENDGE [2], MR. DEEPANKAR PHALNIKAR [3]

[1] *Mr. Aman Singh, Electrical Department , AISSMS IOIT, Maharashtra , India*
[2] *Mr. Nikhil Shendge, Electrical Department , AISSMS IOIT, Maharashtra , India*
[3] *Mr. Deepankar Phalnikar, Electrical Department , AISSMS IOIT, Maharashtra , India.*

ABSTRACT

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.

Keyword: - *Renewable energy ,solar power , six power electronic switches, High Frequency Switching.*

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.

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. Therefore, multilevel inverter technology has been the subject of much research over the past few years. In theory, multilevel inverters should be designed with higher voltage levels in order to improve the conversion efficiency and to reduce harmonic content and electromagnetic interference (EMI).

Conventional 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. But it is difficult to regulate the voltage of these capacitors. Since it is difficult to create an asymmetric voltage technology in both the diode-clamped and the flying capacitor topologies, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. For a single-phase seven-level inverter, 12 power electronic switches are required in both the diode-clamped and the flying-capacitor topologies. Asymmetric voltage technology is used in the cascade H-bridge multilevel inverter to allow more levels of output voltage, so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels. Two H-bridge inverters with a dc bus voltage of multiple relationships can be connected in cascade to produce a single phase seven-level inverter and eight power electronic switches are used. More recently, various novel topologies for seven level inverters have been proposed. For example, 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. However, three dc capacitors are used to construct the three voltage levels, which results in that balancing the voltages of the capacitors is more complex. In, a seven-level inverter topology, configured by a level generation part and a polarity generation part, is proposed. There, power electronic switches of the level generation part switch in high frequency, but ten power electronic switches and three dc capacitors are used. In 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. In, a multilevel dc-link inverter is presented to 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 inverter and to simultaneously overcome the problems of partial shading of individual photovoltaic sources.

1.1 Objective of the System

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.

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 in to 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. Therefore, multilevel inverter technology has been the subject of much research over the past few years. In theory, multilevel inverters should be designed with higher voltage levels in order to improve the conversion efficiency and to reduce harmonic content and electromagnetic interference (EMI).

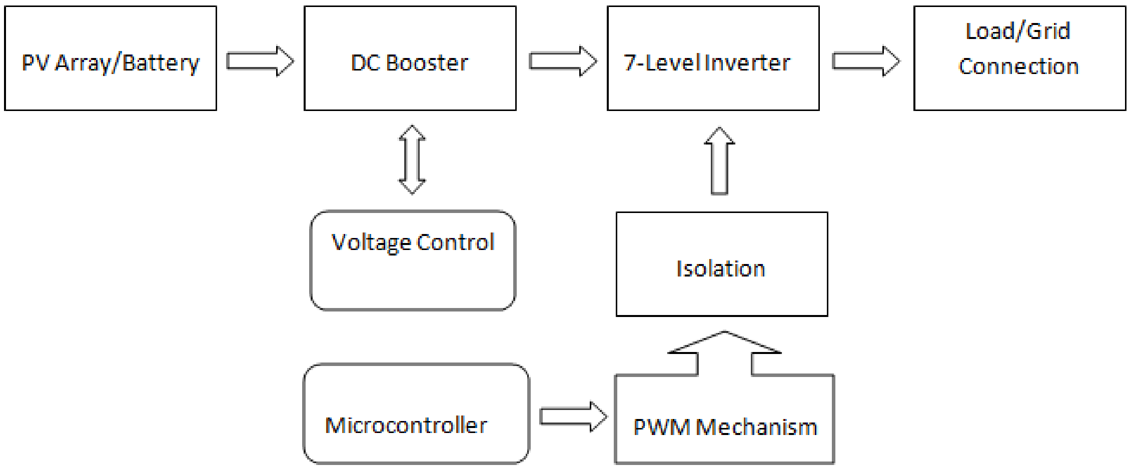

Fig -1: Basic Block Diagram of Objective

2. DIFFERENT TOPOLOGIES FOR SEVEN LEVEL INVERTER

Conventional 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. But it is difficult to regulate the voltage of these capacitors. Since it is difficult to create an asymmetric voltage technology in both the diode-clamped and the flying capacitor topologies, the power circuit is complicated by the increase in the voltage levels that is necessary for a multilevel inverter. For a single-phase seven-level inverter, 12 power electronic switches are required in both the diode-clamped and the flying-capacitor topologies. Asymmetric voltage technology is used in the cascade H-bridge multilevel inverter to allow more levels of output voltage, so the cascade H-bridge multilevel inverter is suitable for applications with increased voltage levels.
Two H-bridge inverters with a dc bus voltage of multiple relationships can be connected in cascade to produce a single phase seven-level inverter and eight power electronic switches are used. More recently, various novel topologies for seven level inverters have been proposed. For example, 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. However, three dc capacitors are used to construct the three voltage levels, which results in that balancing the voltages of the capacitors is more complex. In, a seven-level inverter topology, 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, but ten power electronic switches and three dc capacitors are used. In 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. In, a multilevel dc-link inverter is presented to 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 inverter and to simultaneously overcome the problems of partial shading of individual photovoltaic sources.
Three types of basic topologies are available-

- Diode Clamped Type.
- Flying Capacitor Type.
- Cascaded H-bridge

In the proposed inverter, a cascaded H bridge is used for the following reasons:

- It is easier to control due to an independent voltage source.
- Less power electronic devices are present which reduce the switching losses and harmonics.

2.1 Proposed Topology for Seven Level Inverter

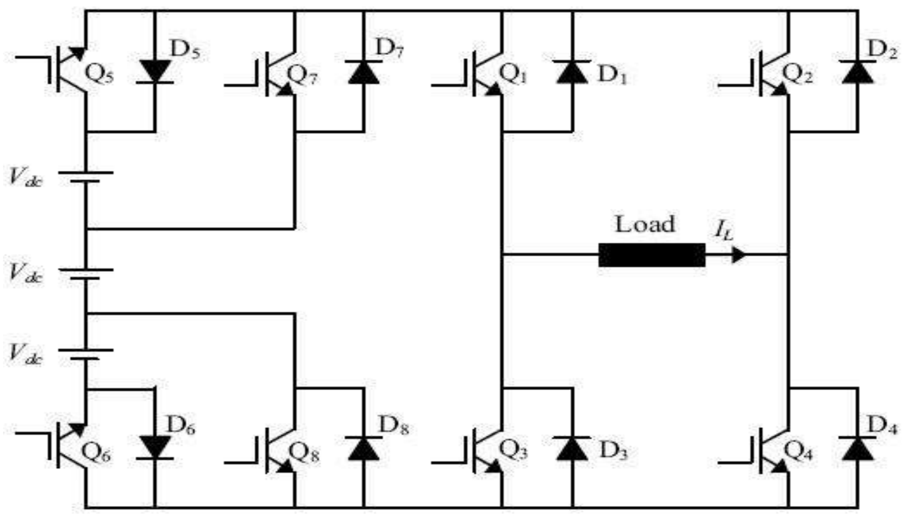

Fig -2: Proposed Seven Level Inverter Circuit

The operation of the seven level inverter can be divided into the positive half cycle and the negative half cycle of the utility. The power electronic switches and diodes are assumed to be ideal. Since the output current of the solar power generation system will be controlled to be sinusoidal and in phase with the utility voltage, the out-put current of the seven-level inverter is also positive in the positive half cycle of the utility. The four modes of operation have been presented as,

- Powering Mode
- Freewheeling Mode
- Regenerating Mode

Powering Mode:

- Load current and voltage have the same polarity.
- In the positive half cycle, when the output voltage is Vdc:

The current pass comprises of the lower supply, D7, Q1, load, Q4, and back to the lower supply.

- When the output voltage is 2Vdc:

Current pass is; the lower source, Q5, the upper source, Q1, load, Q4, and back to the lower source.
In the negative half cycle, Q1 and Q4 are replaced by Q2 and Q3 respectively.

Freewheeling Mode:

- Exists when one of the main switches is turned-off while the load current needs to continue its pass due to load inductance. This is achieved with the help of the anti-parallel diodes of the switches, and the load circuit is disconnected from the source terminals.
- In this mode, the positive half cycle current pass comprises; Q1, load, and D2 or Q4, load, and D3.
- Negative half cycle the current pass includes Q3, load, and D4 or Q2, load, and D1.

Regenerating Mode:

- Part of the energy stored in the load inductance is returned back to the source.
- Happens during the intervals when the load current is negative during the positive half cycle and vice-versa, where the output voltage is zero.
- The positive current pass comprises; load, D2, Q6, the lower source, and D3, while the negative current pass comprises; load, D1, Q6, the lower source, and D4 .

2.2 Firing Angle Calculations

Firing angle calculations are done by dividing the ideal 7-level waveform into equal parts based on the device operations. From the diagram below firing angle is derived.

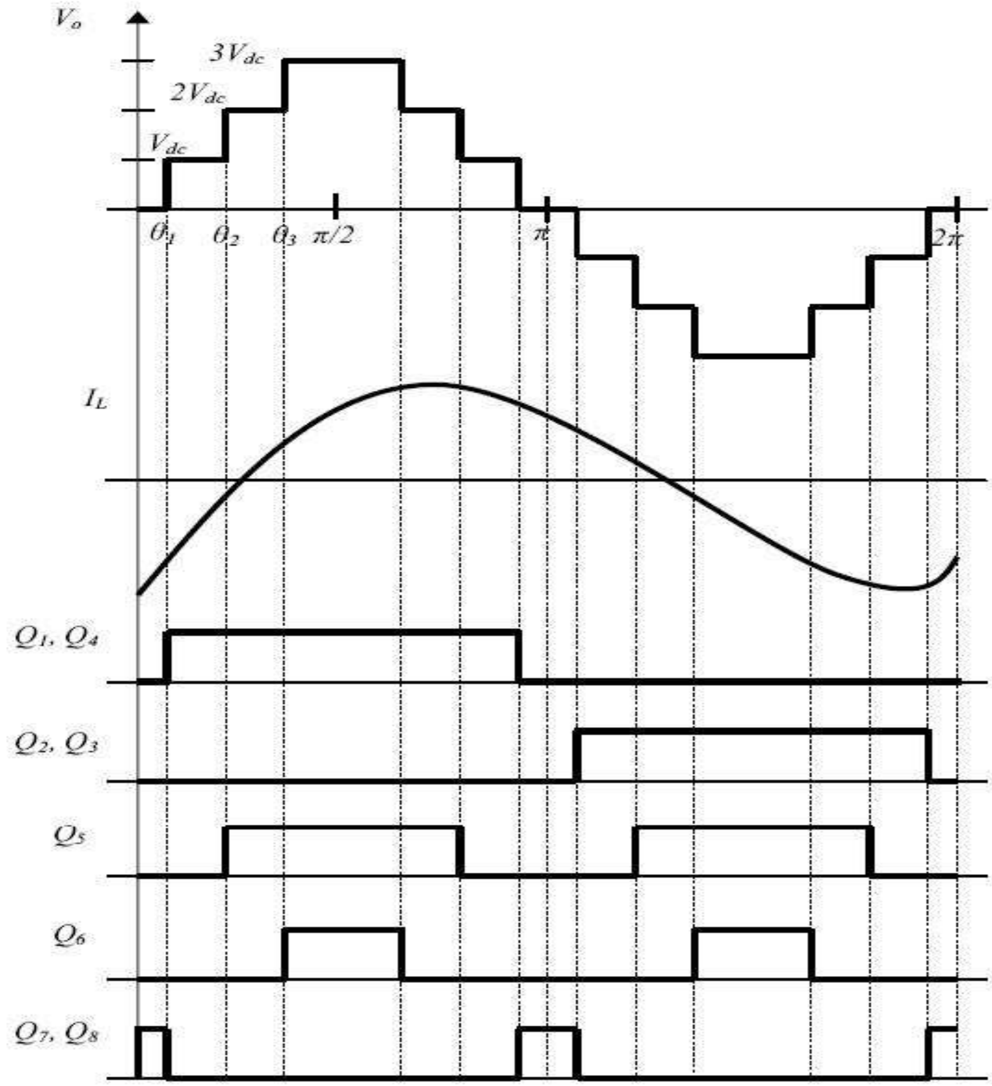

Fig -3: Theoretical Waveform Of Seven Level Inverter

Table -1: Firing Angle Calculations For all MOSFETs employed

Device	Operating Angle (Degrees)	Voltage Level
Q7 & Q8	**60**	**0 V**
Q1 & Q4	**150**	**$+V_{dc}$**
Q6	**60**	**$\pm 3\ V_{dc}$**
Q5	**180**	**$\pm 2\ V_{dc}$**
Q2 & Q3	**150**	**$-\ V_{dc}$**

The output waveform frequency is chosen to be 50 Hz, hence, the following time delay calculation are done to be fed to the Ardino program. Degree to angle conversation for a frequency of 50 Hz:

$$T = \frac{1}{50\,Hz} = 20\,ms$$

$$\frac{360^\circ}{30^\circ} = \frac{20\,ms}{x}$$

Hence, the following calculations are done.

3. TEST AND EXPERIMENTAL RESULTS

Output voltage and current waveforms showing seven levels of the output voltage is observed on the digital oscilloscope:
+Vdc, +2Vdc, 3Vdc, 0, -Vdc, -2Vdc, -3Vdc

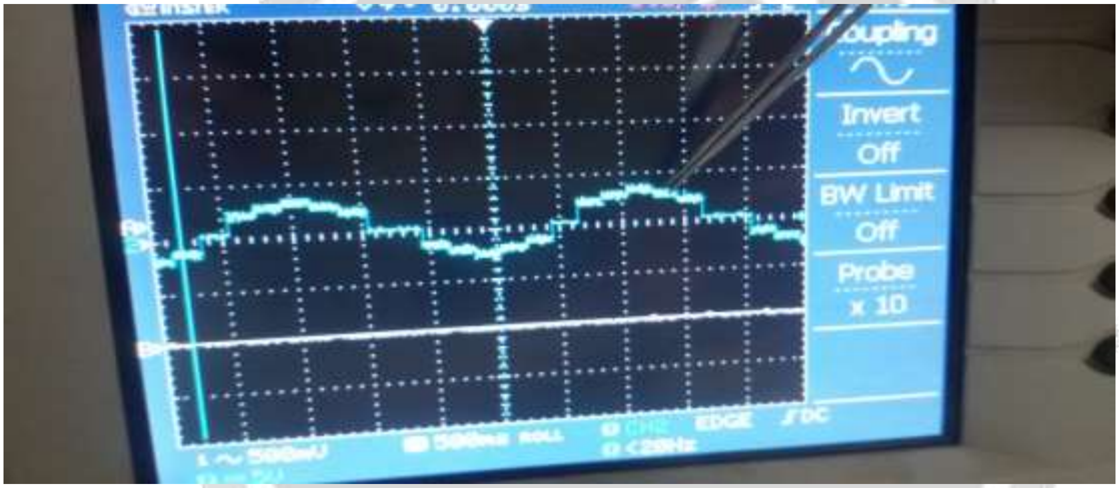

Fig -4 (a): Screen Shots of Digital Oscilloscopes

Fig -4 (b):

Table -2: Experimental Results and Theoretical Results Compared

Parameter	Experimental Value	Observation
Voltage Level (Peak)	12 x 3 = 36 Volts	≈ 9 Volts
Frequency	50 Hz	≈ 49 to 51 Hz

4. CONCLUSIONS

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.

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 in to 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. Therefore, multilevel inverter technology has been the subject of much research over the past few years. In theory, multilevel inverters should be designed with higher voltage levels in order to improve the conversion efficiency and to reduce harmonic content and electromagnetic interference (EMI).

5. REFERENCES

[1]. A New topology of Single-Phase Seven-Level Inverter with Less Number of Power Elements for Grid Connection - G.Gopal, B.Shankaraiah - International Journal of Innovative Technology and Exploring Engineering (IJITEE)

[2]. A 7-Level Single DC Source Cascaded H-Bridge - Multilevel Inverters Control Using Hybrid Modulation - Farid Khoucha, Achour Ales, Abdelkader Khoudiri, Khoudir Marouani

[3]. Analysis and simulation of seven level inverter - K.Surya Suresh and M.Vishnu Prasad - International Journal of Scientific and Research Publications, Volume 2.

[4]. Operation and Design of Multilevel Inverters - Dr. Keith Corzine - University of Missouri – Rolla