MPPT CONTROLLER BASED SOLAR POWER GENERATION USING A MULTILEVEL INVERTER

Kelam Bhargav,
PG Student, Dept of EEE, Sathyabama University, Chennai
bhargavkelam@gmail.com

Santhi Mary Antony .A
Asst.professor, Dept of EEE, Sathyabama University, Chennai
santhieee@yahoo.co.in

Abstract - **Solar energy is a renewable energy that is found abundantly in nature. It is green energy that can be utilized throughout day, therefore maximum energy has to captured from the panel. MPPT algorithm is incorporated to capture maximum energy. A multilevel inverter is a power electronic converter that synthesizes a desired output voltage from several levels of dc voltages of dc voltages as inputs. With an increasing number of dc voltage source, the sinusoidal waveform is obtained by the output voltage, while using a fundamental frequency-switching scheme. The advantage of multilevel inverter is very small output voltage, results in higher output quality and lower switching losses. This paper proposes a MPPT controller based solar power generation system, which consist of dc/dc converter and a new nine-level inverter.**

Keywords: MPPT, Multilevel Inverter, PWM inverter, solar energy.

1. Introduction

The extensive use of fossil fuel has resulted in the global problem of greenhouse emissions. Thus solar power generation is becoming very useful since it pollution less and scarsity of fossil fuel energy is rising, while the cost of solar arrays is decreasing. Solar energy may be widely used in residential application in nature. Since solar energy is not available at night, storing its energy is an important issue in order to have continuous energy availability.

An inverter is necessary to convert the dc power to ac power. since output voltage of a solar cell array is low,a dc-dc power converter is used in a small-capacity solar power generation system. The active devices and passives in the inverter produce a power loss. The power loss due to active devices include both conduction losses and switching losses. The switching losses is proportional to the voltage and the current.

The switching operation for a multilevel inverter is in order to improve power conversion efficiency. In theory multilevel inverter should be designed with higher voltage levels in order to improve the conversion efficiency and reduce harmonic content and electromagnetic interface. The need of multilevel inverter is to give a high output power from medium voltage source. Source like batteries, super capacitors, solar panel are medium voltage sources.

Conventional multilevel inverter topologies include the diode clamped and flying capacitor and cascade multilevel inverter. The diode clamped multilevel inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. The maximum output voltage is half of the input dc voltage. The flying capacitor multilevel inverter complicated way of inversion ,because the capacitors need to be pre charged, and is somewhat similar to diode clamped method. The difference is that clamping is done through capacitors instead of diodes. Diode-clamped and the flying capacitor multilevel inverter use capacitor to develop several voltage levels.

1.1 Existing System

In that ,existing system has a new solar power generation system. The solar power generation system is composed a dc-dc power converter and a seven level inverter The seven level inverter contains only six power electronics switches. This switch is switched at high frequency at any time to generate the seven level output voltage, the switching losses is reduced, and the power efficiency is improved. The filter inductor also reduced because there is a seven level output voltage.

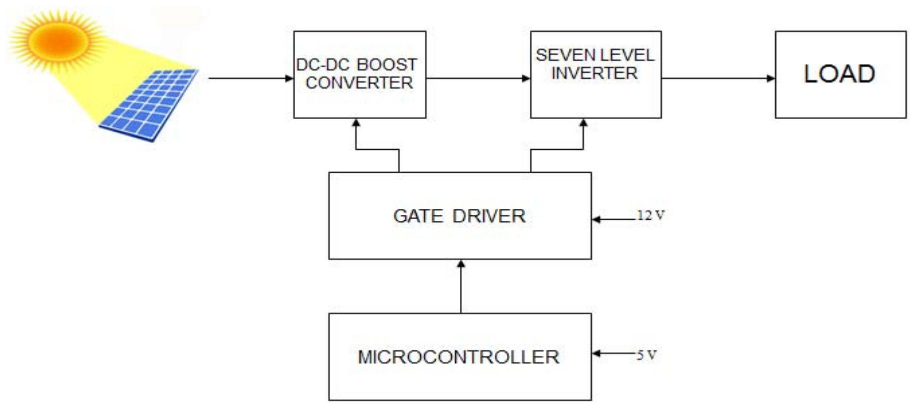

Fig .1. Block diagram of existing system

The existing system block diagram shown in figure 1.The input voltage of the solar panel is dc and it takes the dc input from the solar panel. The solar panel directly connected to the dc-dc boost converter. The dc-dc converter is an electronic circuit and DC-DC Converter is required to implement MPPT algorithm. Microcontroller that implements MPPT algorithm, controls DC-DC converter MOSFET and displays system information.

1.2 Proposed System

The proposed system block diagram shown in figure. The input voltage of the solar panel is dc and it takes the dc input from the solar panel. The dc-dc boost converter boost up the input voltage and gives to the multilevel inverter. The multilevel inverter is synthesize a near sinusoidal voltage from several levels of dc voltages, as number of voltage levels increase, the synthesized output waveform has more steps, which provides a stair-case wave that approaches a desired waveform. The steps are added to waveform the harmonics distortion of the output wave form decrease, approaching zero as the number of voltage level increase. The gate driver circuit acts just like a pulse generator.

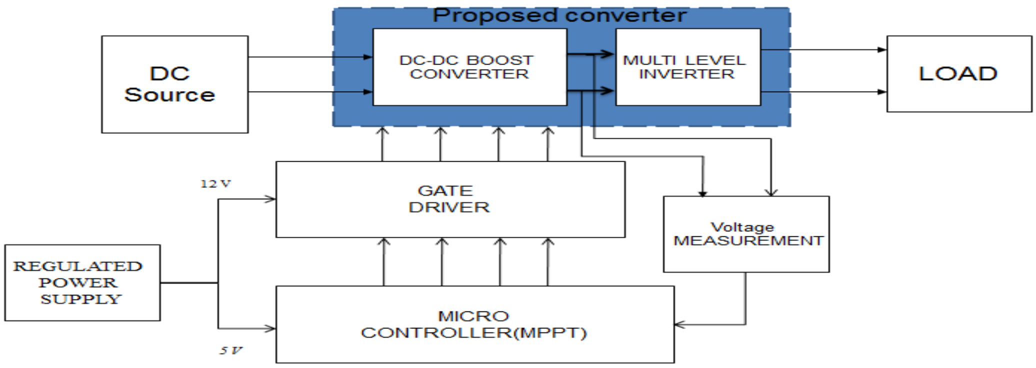

Fig .2. Block diagram of proposed system

The gate driver are electronic circuits that apply correct power levels to MOSFET or IGBT. The MOSFET requires 10-15volts supply to operate. The micro-controller circuit is used to give pulse to MOSFET circuit. It can give the pulse up to 5volts. The microcontroller acts as MPPT. A MPPT is an electronic dc-dc converter that optimizes a match between the solar array and the battery bank or utility grid. The power point tracker is a high frequency dc-dc converter. The converter a high voltage dc output from the solar panels down to the lower voltage need to charge batteries.

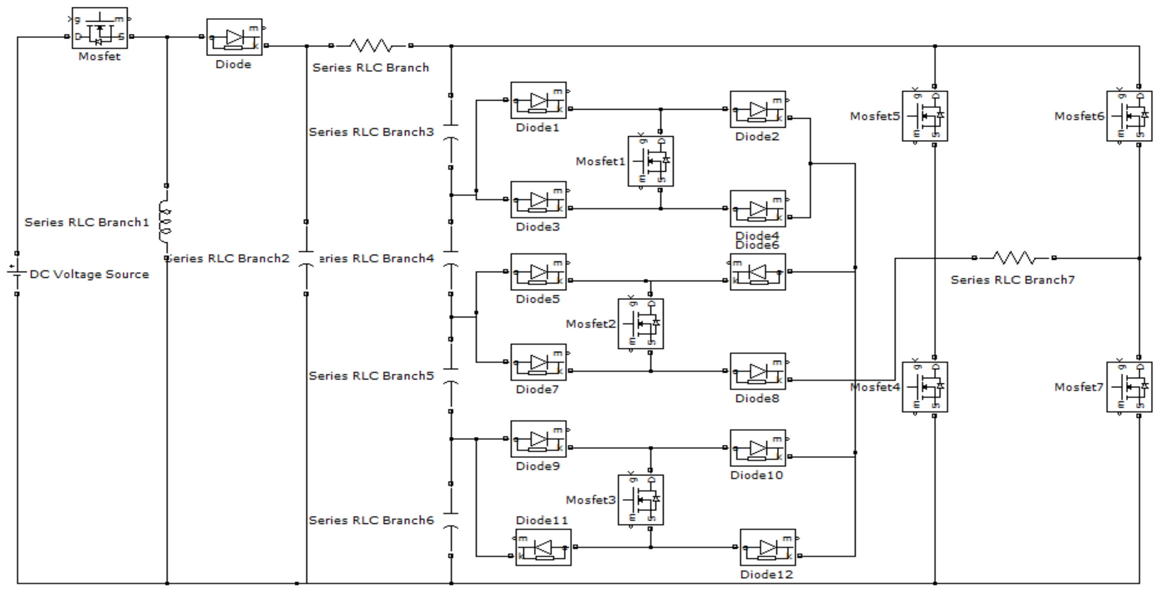

Fig.3. circuit diagram of proposed system

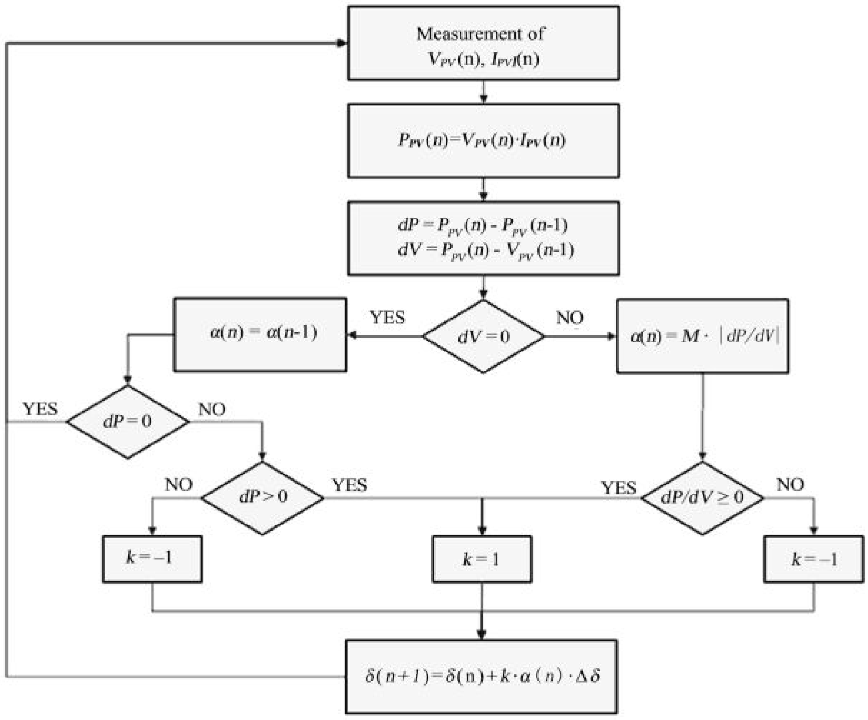

Fig.4. Algorithm

2. Circuit configuration

The solar power generation system is composed of a solar cell array, a dc-dc power converter, and a nine level inverter. The solar cell array is connected to the dc-dc power converter. The dc-dc power converters developed to maximize the energy harvest for photovoltaic system. The dc-dc power converter converts the output power of the solar cell array into two voltage sources, which are supplied to the nine-level inverter. The nine level inverter is composed of a capacitor selection circuit and a full bridge converter ,connected in a cascade. The capacitor selection circuit find the discharge of two capacitors while individually discharge of two capacitors. The capacitor selection circuit output a three level dc voltage. The full bridge power converter further converts this three level dc voltage to a nine-level ac voltage that is synchronized with the utility voltage. In this way the solar power generation system generate a sinusoidal output current that in phase with the utility voltage and is fed into the utility, which produce a unity power factor.

2.1 DC-DC power converter

The buck-boost converter is a type of dc-dc converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The dc-dc power converter is incorporates a boost converter and a current-fed forward converter. The boost converter is composed of an inductor ,a power 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, power electronics switches SD1 and SD2, a transformer, and diodes. The current-fed forward converter charges capacitor C1 of the seven level inverter. The inductor and the power electronics switch SD1 of the current-fed forward converter are also used in the boost converter. The dc-dc power converter when SD1 is turned on. when SD1 is turned off and SD2 is turned on. The capacitor c1 is connected to capacitor C2 in parallel through the transformer. Since capacitor C1 and C2 are charged in parallel by using the transformer, the voltage ratio of capacitor C1 and C2 is the same as the turn ratio of the transformer. The voltage of C2 can be represented as

$$Vc2=1/1-D\ Vs$$

Where Vs is the output voltage of solar cell array and D is the duty ratio of Sd1.The voltage of capacitor C1 can be represented as

$$Vc1=1/2(1-D)\ Vs$$

2.2 Nine level inverter

The nine-level inverter is controlled by the current-mode control, and pulse width modulation is use to generate the control signals for the power electronics switches.The operation of nine level inverter can be divided into the positive half cycle and negative half cycle of the utility. While the voltage of both capacitor 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 nine level inverter is also positive and in the positive half cycle of the utility. The operation of the nine level inverter in the positive half cycle of the utility can be further divided into four modes.The output voltage of the nine-level inverter must be switched in two levels, according to the utility voltage. The output voltage of the nine-level inverter has the voltage level:Vdc,2Vdc/3,Vdc/3,4Vdc/3,0,-Vdc/3,-2Vdc/3 ,-Vdc,-4Vdc/3.

TABLE 1. Switching sequence:

Modes	S1	S2	S3	S4	S5	S6	S7
4	1	0	0	1	0	0	0
3	1	0	0	1	0	0	1
2	1	0	0	1	0	1	0
10	1	0	0	1	0	0	0
-1	0	1	0	0	1	0	0
-2	0	1	1	0	0	1	0
-3	0	1	1	0	0	0	1
-4	0	1	1	0	0	0	0

Mode 1:

The operation of mode 1 shown in below fig. The positive output voltageVdc. The switch S1 is on connecting to load positive terminal to Vdc. Switch S4 is on, connect the load negative terminal to ground. All other controlled switch are off; voltage applied to the load terminal is Vdc.

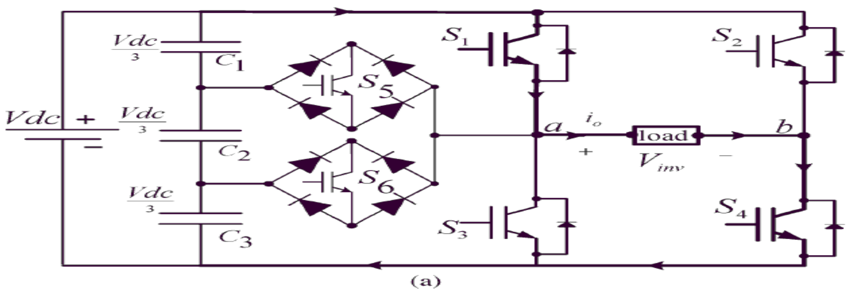

Fig 2.1 Mode 1

Mode 2:

The operation of mode 2 shown in below fig. Two-third positive output (2*V*dc/3): The bi-directional switch *S*5 is ON, connecting the load positive terminal, and *S*4 is ON, connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is 2*V*dc/3.

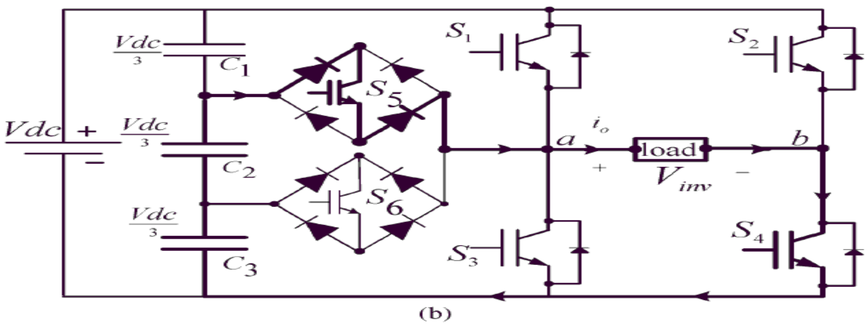

Fig 2.2 Mode 2

Mode 3:

The operation of mode 3 shown in below fig. One-third positive output (Vdc/3): The bi-directional switch S6 is ON, connecting the load positive terminal, and S4 is ON, connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is Vdc/3.

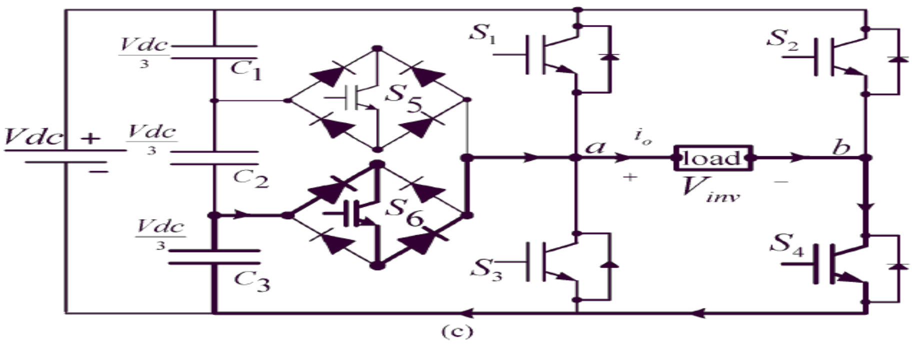

Fig 2.3 Mode 3

Mode 4:

The operation of mode 4 shown in below fig. Zero output: This level can be produced by two switching combinations; switches S3 and S4 are ON, or S1 andS2 are ON, and all other controlled switches are OFF; terminal ab is a short circuit, and the voltage applied to the load terminals is zero.

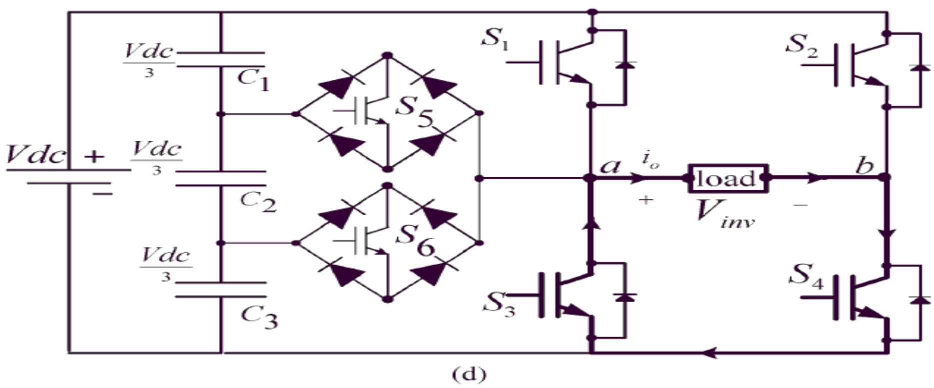

Fig 2.4 Mode 4

Mode 5:

The operation of mode 5 shown in below fig. One-third negative output (−Vdc/3): The bi-directional switch S5 is ON, connecting the load positive terminal, and S2 is ON, connecting the load negative terminal to Vdc. All other controlled switches are OFF; the voltage applied to the load terminals is −Vdc/3.

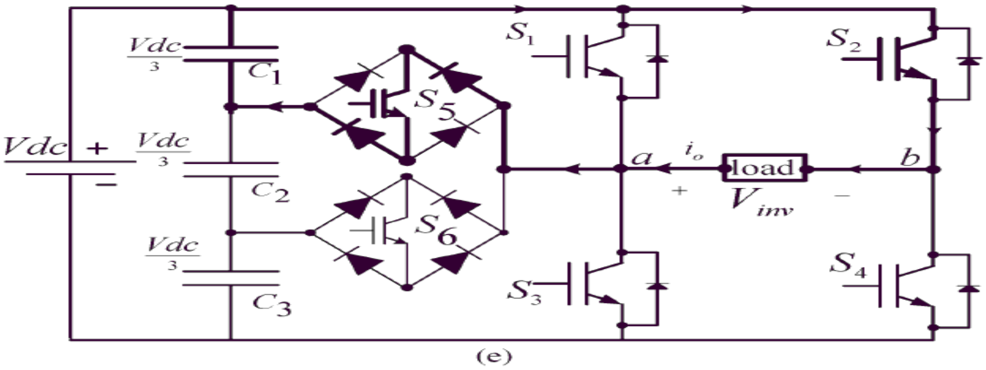

Fig 2.5 Mode 5

Mode 6:

The operation of mode 6 shown in below fig. Two-third negative output (−2Vdc/3): The bi-directional switch S6 is ON, connecting the load positive terminal, and S2 is ON, connecting the load negative terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is −2Vdc/3.

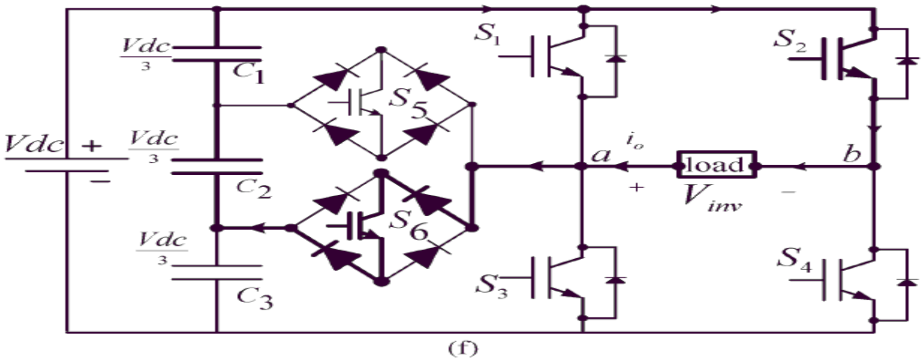

Fig 2.6 Mode 6

Mode 7:

The operation of the mode 7 shown in below fig. Maximum negative output (−Vdc): S2 is ON, connecting the load negative terminal to Vdc, and S3 is ON, connecting the load positive terminal to ground. All other controlled switches are OFF; the voltage applied to the load terminals is −Vdc.

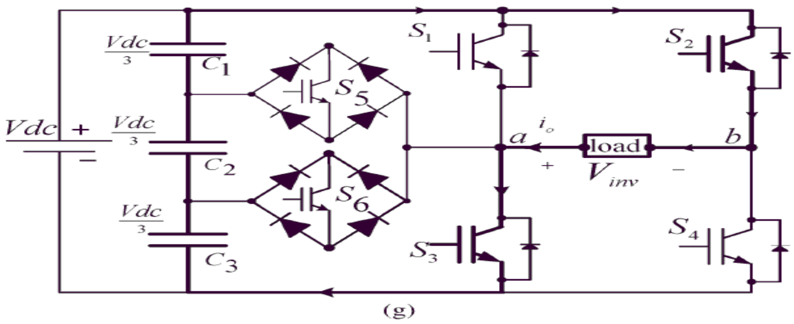

Fig 2.7 Mode 7

Simulation proposed system:

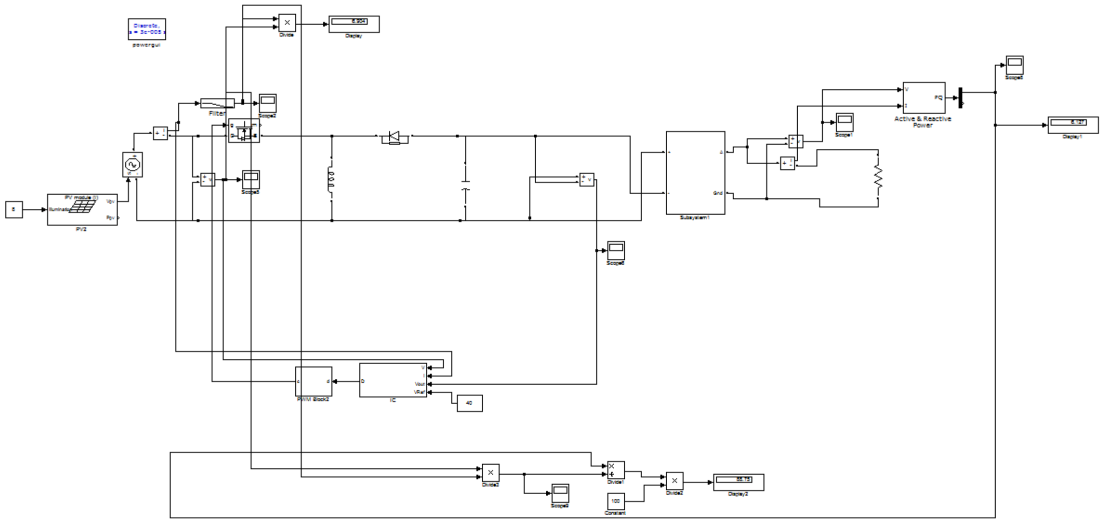

Figure3:Proposed circuit diagram

The operation of the proposed simulation shown in above figure. The photovoltaic system use a solar panel. The solar power is radiant energy produced sunlight. Any from of energy that moved from one place to another via radiation. However sunlight comes and go, bird, clouds etc. The panel output to fluctuate and thus solar fans would likely stop. Solar panel suitable for 12v battery charging and generally have voltages rated at around 16-17v.The solar panel input is 12v dc and then give to the low pass filter. A low pass filter is a filter that passes signals with a frequency lower than a certain cutoff frequency. The composed of a dc-dc power converter and a nine level inverter. The filter inductor parallel connected to the capacitor. The purpose of filter inductor is used to process the switching harmonic of the inverter. So the power losses is propositional to the switching losses. The nine level inverter is composed of a capacitor selection circuit and a full bridge power converter which is connected in cascade. The operation of the nine level inverter can be divided into the positive half cycle and the negative half cycle of the utility. The proposed nine level inverter are that only eight power electronic switches are used, only one power electronic switch is switched at high frequency at any time. The conventional multi-level inverter reduced topologies, in which at least four semi conductor device are conducting in series. Therefore the conduction loss of the proposed nine level inverter output voltage is reduced.

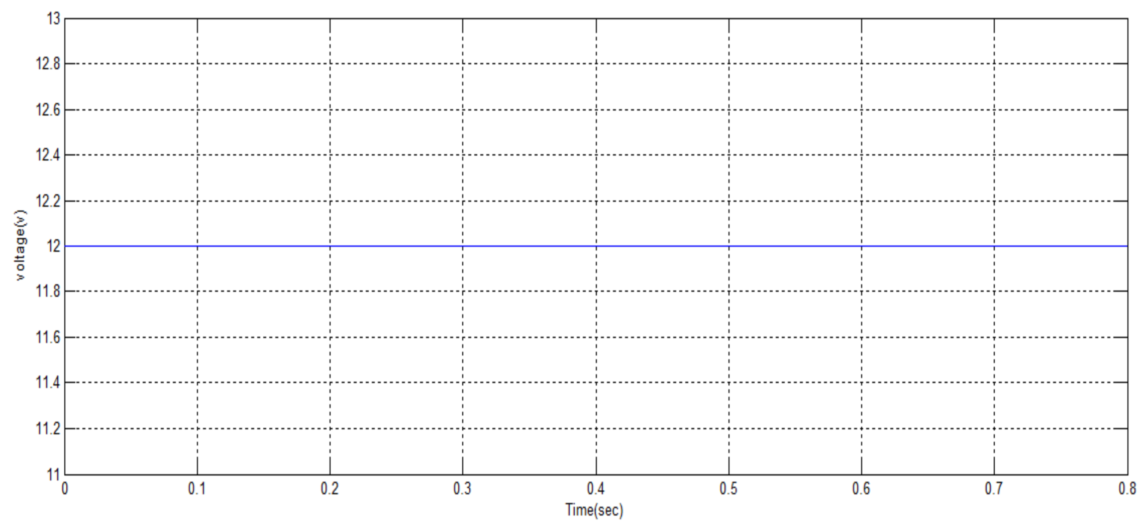

Fig .5.Input voltage waveform

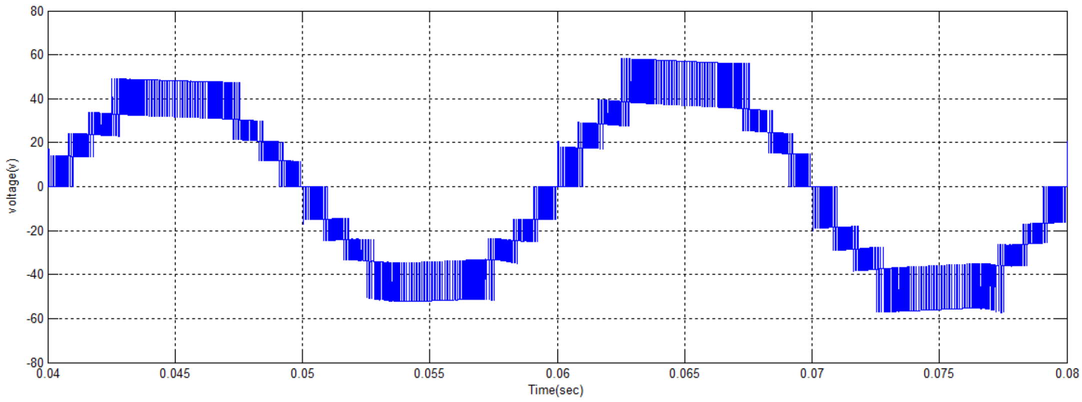

Fig.6.output voltage waveform

The proposed nine level output voltage is shown in figure. The output voltage of the nine level inverter has nine voltage levels. The output voltage of the nine level inverter is 60v.

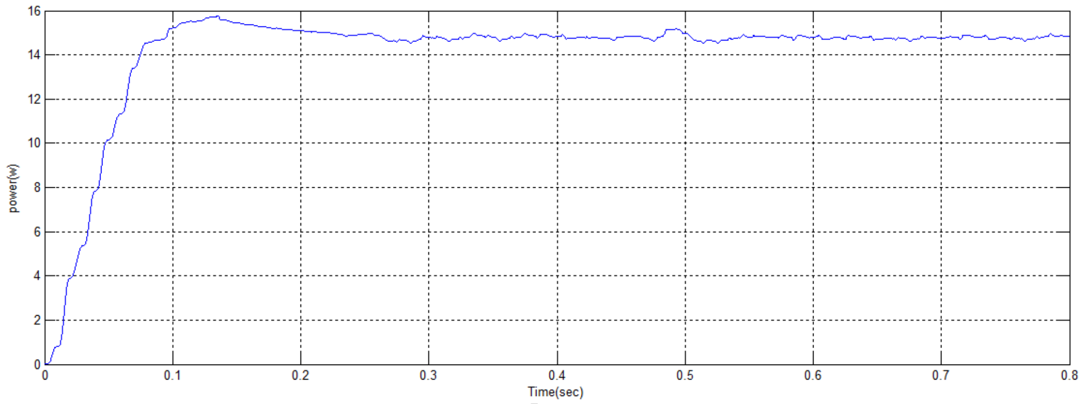

Fig.6. Output power waveform

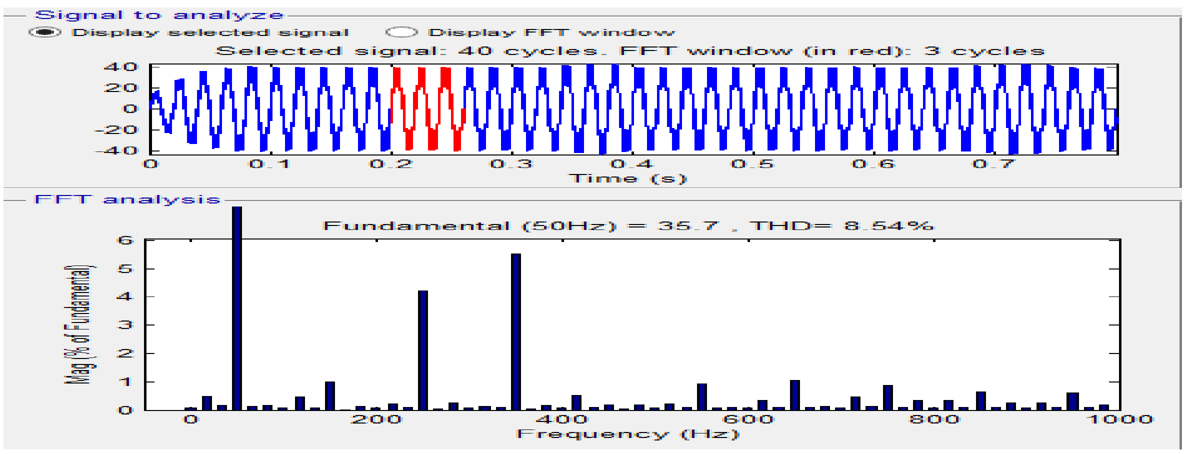

Fig.7.THD waveform

TABLE.2.Results

	Existing system	Proposed system
Input voltage	12V	12V
Input current	1.4A	1.4A
Input power	16.08W	16.17W
Output voltage	60V	60V
Output current	0.6A	0.6A
Output power	12.8W	14.84W
Efficiency	73%	91.8%

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. The proposed solar power generation system is composed of a buck-boost converter and a nine-level inverter. The switching power loss and improves the power efficiency. The proposed solar power generation system generates a nine-level output voltage and outputs a sinusoidal current that in phase with the utility voltage. The proposed solar power generation system can effectively trace the maximum power of solar cell array.

REFERENCES

[1] R.A.Mastromauro,m.liserre,anda.dellaquila,"control issues in single-stage photovoltaic system: MPPT,current and voltage control." IEEE trans.ind.informat.,vol.8,pp.241-254,may.2012.

[2] Z.Zhao,M. Xu,Q.Chen,J.S.jasonlai,and Y.H.cho,"derivation the operation of a Z-source inverter for a boost–buck converter-based high-efficiency pvinverter,"IEEEtrans.power electron.,vol.27,no.3,pp.1304-131 mar.2012

[3] M.Hanif,M.Basu,and K.Gaughan,"Understanding the operatio of a Z-source inverter for photovoltaic application with adesign example,"IETpower electron.,vol.4,no.3,pp.278-287 mar.2011

[4] J.-M. Shen, H. L. Jou, and J. C. Wu, "Novel transformer-less grid connected power converter with negative grounding for photovoltaic generation system," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1818–1829, Apr. 2012.

[5] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics Converters, Applications and Design, Media Enhanced 3rd ed. New York, NY, USA: Wiley, 2003.

[6] K. Hasegawa and H. Akagi, "Low-modulation-index operation of a five-level diode-clamped pwm inverter with a dc-voltage-balancing circuit for a motor drive," IEEE Trans. Power Electron., vol. 27, no. 8, pp. 3495–3505, Aug. 2012.

[7] E. Pouresmaeil, D. Montesinos-Miracle, and O. Gomis-Bellmunt, "Control scheme of three-level NPC inverter for integration of renewable energy resources into AC grid," IEEE Syst. J., vol. 6, no. 2, pp. 242–253, Jun. 2012.

[8] S. Srikanthan and M. K. Mishra, "DC capacitor voltage equalization in neutral clamped inverters for DSTATCOM application," IEEE Trans. Ind.Electron., vol. 57, no. 8, pp. 2768–2775, Aug. 2010. SS

[9] M. Chaves, E. Margato, J. F. Silva, and S. F. Pinto, "New approach in back-to-back m-level diode clamped multilevel converter modelling and direct current bus voltages balancing," IET power Electron., vol. 3, no. 4, pp. 578–589, 2010.

[10] J. D. Barros, J. F. A. Silva, and E. G. A Jesus, "Fast-predictive optimal control of NPC multilevel converters," IEEE Trans. Ind. Electron., vol. 60, no. 2, pp. 619–627, Feb. 2013.

[11] A. K. Sadigh, S. H. Hosseini, M. Sabahi, and G. B. Gharehpetian, "Double flying capacitor multicell converter based on modified phase-shifted pulse width modulation," IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1517–1526,Jun. 2010.

[12] S. Thielemans, A. Ruderman, B. Reznikov, and J. Melkebeek, "Improved natural balancing with modified phase-shifted PWM for single-leg five-level flying-capacitor converters," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1658–1667, Apr. 2012.

[13] S. Choi and M. Saeedifard, "Capacitor voltage balancing of flying capacitor multilevel converters by space vector PWM," IEEE Trans. Power Delivery, vol. 27, no. 3, pp. 1154–1161, Jul. 2012.

[14] L. Maharjan, T. Yamagishi, and H.Akagi, "Active-power control of individual converter cells for a battery energy storage system based on a multilevel cascade pwm converter," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1099–1107, Mar. 2012.

[15] X. She, A. Q. Huang, T. Zhao, and G. Wang, "Coupling effect reduction of a voltage-balancing controller in single-phase cascaded multilevel converters," IEEE Trans. Power Electron., vol. 27, no. 8, pp. 3530–3543, Aug. 2012.

[16] J. Chavarria, D. Biel, F. Guinjoan, C. Meza, and J. J. Negroni, "Energy balance control of PV cascaded multilevel grid-connected inverters under level-shifted and phase-shifted PWMs," IEEE Trans. Ind. Electron., vol. 60, no. 1, pp. 98–111, Jan. 2013.

[17] J. Pereda and J. Dixon, "High-frequency link: A solution for using only one DC source in asymmetric cascaded multilevel inverters," IEEE Trans.Ind. Electron., vol. 58, no. 9, pp. 3884–3892, Sep. 2011.