

Simulation of 9-level flying capacitor inverter connected with the Solar System and EV Charger.

Harsh N Patel¹, Prof. Ruchit Soni²

Electrical Engineering Department, Indus university, ahmedabad

Electrical Engineering Department, Indus university, ahmedabad

Abstract: Renewable energy generation is rapidly increasing all over the world. Because of clean, green and cheaper than fossil fuel energy. In Renewable energy, we are mostly using photovoltaic systems. This system is easy to install anywhere. So in these industries, their many types of machine converters are there to use. Proper knowledge is required of when and where to use it. In this paper, we are simulating a 9-level flying capacitor multilevel inverter and Ev vehicle charger connected with the photovoltaic system. The simulation block diagram of this system is explained.

Keywords: 9-level flying capacitor multilevel inverter, solar panel, EV charger.

1. Introduction

In this next generation, the world is aware of renewable energy. An increasing number of renewable energy systems are very high renewable energy like solar energy, wind turbine energy, hydro energy ext. in this list solar energy is the top used system in the world. In this system, electricity is directly converted from sunlight. Which is easily available and cheaper than fossil fuel. This system is easy to install anywhere and has clean energy. The solar system gives an output of the dc voltage. So in this case we are using a dc-ac converter to convert dc voltage into the ac voltage for the house. A conventional h-bridge inverter gives an output of the square waveform. So basically that inverter contains many odd numbers of harmonics and dv/dt stress is also high.

We can get better results from the multilevel inverter compared to this. The multi-level inverter is capable of high-level voltage and high-power output applications. The waveform is synthetic with better harmonics spectrums.[1]

There are three types of multilevel inverters 1) diode clamped 2) cascaded h-bridge 3) flying capacitor clamped. In a diode-clamped inverter, the number of diodes is increased as the level of the inverter will increase. In a three-level diode clamp inverter, there is a two diode connected. In five level diode clamp inverter, there are four diodes connected.

In cascaded h-bridge inverter will use in high-power machines. In this inverter separate dc source is used. This inverter is complex to design and hard to understand. In a Flying capacitor clamped inverter number of flying capacitors will increase as the increase of level of the inverters. In a five-level inverter, 10 flying capacitors are used.[2]

Use of the flying capacitor multilevel inverter there are common problems like unbalancing of the capacitors. In this case, we have to make sure that the capacitor should balance. If the capacitor is not balanced it can reduce the life of the machine. There are many techniques to balance the capacitors. Like redundant switching state of the IGBT . Use of the resistor, inductor and capacitor filter in parallel to the load. And best is to self-balancing the capacitors.[3]

The solar system is connected with the inverter directly and the EV charger is connected parallel with the solar system. basically in this ev can give supply to the house when an absence of solar power. Using the multilevel inverter. Dc/dc converter is connected between the inverter and the EV charger. To boost the battery voltage. Dc voltage from the battery will convert into the ac throu the flying capacitor multilevel inverter to the house.

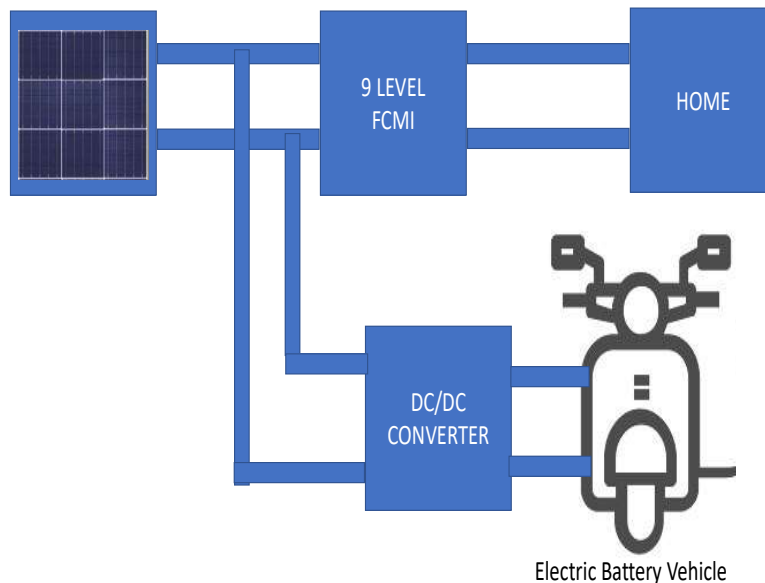


Figure 1. Diagram of the system

In figure 1 solar system is generate electricity in dc Voltage. The inverter converts the dc voltage to the ac voltage. After that, the power will supply to the home. EV charger is connected parallel to the solar system.. Between the inverter and EV charger, dc/dc converter is connected. Dc/dc converter boosts the voltage of the battery. The boosted voltage will supply to the inverter.[4]

In the solar system, renewsys company panels were used in the MATLAB simulation. The total number of panels is 20 panels Connected in series. Rating of the each panel is 330watt. A total of 6.6kw system is connected in the series. The short circuit voltage of the solar panel is 37.67v. The ideal rating of the panel in normal conditions is shown in figure 2. The short circuit current is 9.50 in normal weather conditions. Our simulation system is running at the 1000 irradiation and 25°C temperature of the weather. So the output from the solar system is 500 voltage.

2. Photovoltaic system

In the solar system, renewsys company panels were used in the MATLAB simulation. The total number of panels is 20 panels Connected in series. Rating of the each panel is 330watt. A total of 6.6kw system is connected in the series. The short circuit voltage of the solar panel is 37.67v. The ideal rating of the panel in normal conditions is shown in figure 2. The short circuit current is 9.50 in normal weather conditions. Our simulation system is running at the 1000 irradiation and 25°C temperature of the weather. So the output from the solar system is 500 voltage..

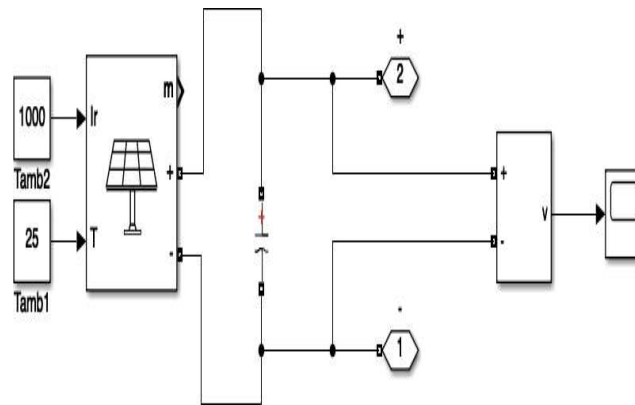


Figure 2. Solar Panle

3. Electric Vehicle

Here I connected an electric vehicle to the system. as shown in figure 1. From this, Dc/dc converter is connected to the electric vehicle. This converter is a boost converter to boost the solar system's voltage. The total capacity of the battery is 3000Wp. The battery is made of lithium-ion. battery rating of the electric vehicle is 60v and 50Ah. If the solar system gives a supply of 500v. and the rated current is 9amps. boost converter will boost the voltage of the solar from 500v to 740v. boosted voltage is the supply for the battery And the battery will start charging. We can use a CCS2 type charger for charging the electric vehicle. Which can give an output of 2kw and charge the battery

Table 1 : Parameters of the Electrical vehicle battery

Electric vehicle battery	
Quantity	Value
Nominal Voltage	60
Nominal Capacity	50Ah
Energy	3000Wp
Efficiency	99%

4. 9-Level Flying Capacitor Multilevel Inverter.

In this 9-level flying capacitor multilevel inverter, capacitors are connected in series with the clamped switching cells. IGBT is used for the switching control. Reactive and active power was controlled by the inverter. There is a switching loss in this system. the main drawback of this system is output result will be half of the input result.

TOPOLOGY

The topology consists of the capacitors and switching devices. Theoretically, this topology has the power to give infinite levels but there are many limitations in practice to achieve the results. In this paper, I will achieve the 9-level output from the inverter. This inverter has IGBT at every leg for switching purposes. The number of levels depends on the number of switches in each leg. In this capacitors are near to the load. That capacitor has low voltage. And which capacitors are near to the source voltage that capacitors have high voltage.[5]

CALCULATION

The formula is to obtain the numbers of the capacitor and switching devices.

For 'n' level inverters.

Number of,
balancing capacitors $N_{bc} = (n-1)(n-2)/2$

switching devices $N_{sd} = 2(n-1)$

DC bus capacitors $N_c = (n-1)$

So for the 9-level flying capacitor inverter. A number of the capacitor, and IGBT.

For the balancing capacitor $N_{bc} = (9-1)(9-2)/2$

$$= (8)(7)/2$$

$$= 28$$

So we need 28 balancing capacitors for the inverter.[6]

For the Switching devices $N_{sd} = 2(9-1)$

$$= 16$$

We require 16 nos. of IGBT for the switching purpose.

For the DC bus capacitors $N_c = (n-1)$

$$= 8$$

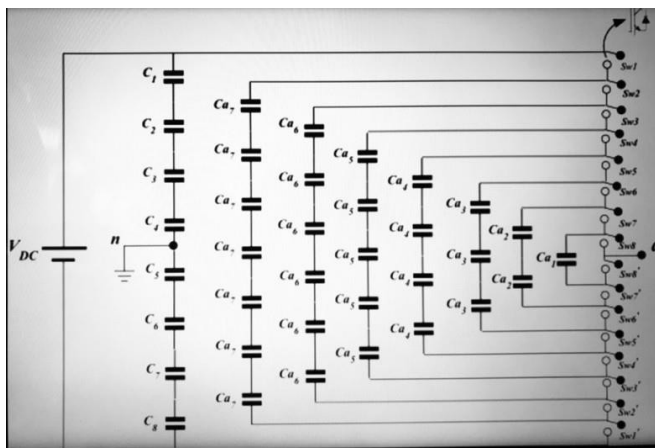


Figure 3 : 9-level flying capacitor multilevel inverter

As shown in figure 3. In the last limb which is near the dc voltage is the bus capacitor. Eight capacitors are connected in series with each other. The other 28 capacitor is a flying capacitors connected with the IGBT switching device. For Turning on and turning off the IGBT Pulse will give through the pulse generator. For example, we have to turn on leg one. So IGBT no 1,2,3,4,5,6,7 and 9 switch will turn on. Another switch will remain to turn off. The switching of the IGBT inverter will give us a voltage level.

Table 2 : IGBT Switching on-off

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16
7E	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
6E	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0
5E	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0
4E	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
3E	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0
2E	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0
E	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
(-E)	1	1	1	0	1	1	0	1	0	1	1	1	1	1	1	1
(-2E)	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1
(-3E)	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1
(-4E)	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1
(-5E)	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
(-6E)	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
(-7E)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

As shown In table 2 Possibility for the switching of the IGBT for all the switches so here we take reference from which switch will turn off or on. From the nine-level inverter, we will get voltage level is $0, +V, +2V, +3V, +4V$. this is a positive cycle of voltage. For negative cycle. $0, -v, -2v, -3v, -4v$ will be the output. The switching IGBT switch is like this. The total supply voltage is $8E$. so if the inverter wants to turn on the one flying capacitor then switch no 1,2,3,4,5,6,7 and 9.

Table 3: Switching pulse for the positive side

IGBT No.	Period(sec)	Pulse Width in %	phase delay(sec)
1	0.02	38.88888889	0.001111111
2	0.02	38.88888889	0.001111111
3	0.02	27.77777778	0.002222222
4	0.02	21.77777777	0.002222222
5	0.02	16.66666667	0.003333333
6	0.02	16.66666667	0.003333333
7	0.02	0.555555556	0.004444444
8	0.02	0.555555556	0.004444444

Table 4: Switching pulse for the negative side.

IGBT No.	Period(sec)	Pulse Width in %	phase delay(sec)
9	0.02	5.555555556	0.014444444
10	0.02	5.555555555	0.014444444
11	0.02	16.66666666	0.013333333
12	0.02	16.66666666	0.013333333
13	0.02	27.77777777	0.012222222
14	0.02	27.77777777	0.012222222
15	0.02	38.88888888	0.011111111
16	0.02	38.88888888	0.011111111

In table 3 and table 4. Mention the pulse width, phase delay and the period of time in sec. all 16 IGBT work as the given pulse to the pulse generator. The Switching Pulse output is shown in the figure 09 to 13 respectively.

5. Electric Vehicle

Now boost converter is connected between the battery and the PV array. Basically, an electric vehicle's battery is connected to the IGBT and inductor. The battery capacity is 60v. when the converter is in working condition the power flow from the inductor. So, in the inductor magnetic energy will produce. Energy will store in the inductor.

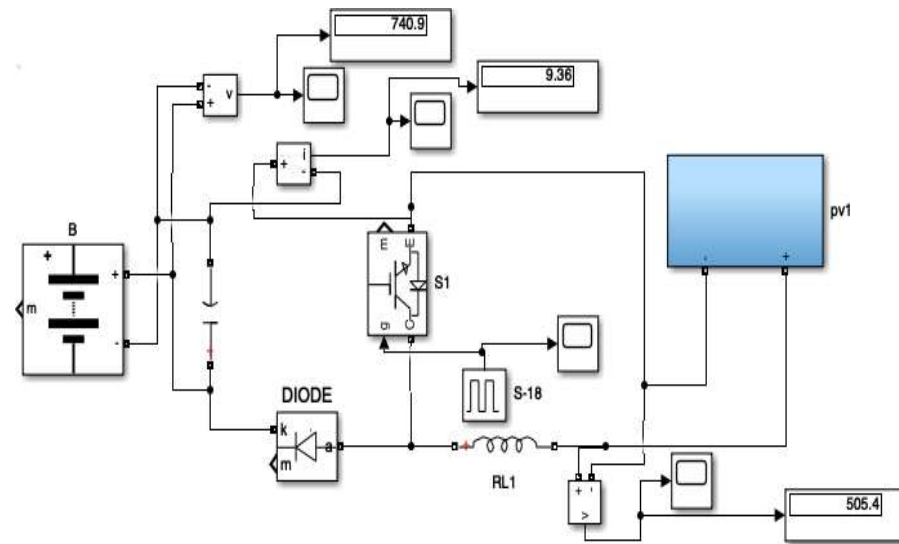


Figure 4 : Simulation of the DC/DC Booster

The polarity of the inductor is applied. When IGBT is turned off. The current will stop flowing. The IGBT switch is turned off so the power will flow from the inductor, diode and capacitor. after that circuit will be complete. The output capacitor is still charged it can't discharge through the diode. The polarity of the voltage across the inductor is applied

The IGBT switch is turned on. So turning all the IGBT all the current will flow from the IGBT. The power source will not short-circuit immediately. So the inductor current ramp up slowly from that. Inductor's nature is to flow the current smoothly. It's not like to change in current immediately. Opposite polarity of voltage will supply to it using the energy stored in the magnetic field to maintain the current flow. The output capacitor is charged higher voltage than before. That means we are boosting dc voltages successfully.

6. Results

9-level flying capacitor multilevel inverter which is connected with the PV array and the electric vehicle battery and the home. The total number of Kw is 6.6 kw system is simulated. The electric vehicle battery is also charged from the solar panel and solar system is also provides power to the household as simulated in the Matlab.

Pv array is working in 1000 irradiation and 25c temperature. The output of the PV array is 500v as shown in fig.05. that voltage will be supplied to the 9-level flying capacitor multilevel inverter. Dc voltage will be converter into the ac from the inverter.

The solar panel feeds the power to the home and also to the EV charger to charge the battery. Dc/dc converter is connected between the EV vehicle and the solar panel. Solar panel voltage is boosted for the EV vehicle to charge the battery.

The output of the solar system is 500V. and from the dc/dc boost converter get the output voltage is 740V. and the current is 9.36 amps. As shown In figures 06 and 07 and the battery will charge from the solar panel.

The final output of the 9-level flying capacitor multilevel inverter of the PV array is half of the input voltage. The input of the 9-level inverter from the PV array is 500v and the output voltage is 240 Voltage as shown in fig.08.

This is the off-grid system. solar panel installed capacity is 6.6kw. total consumption of our home is 2kw. total and EV battery consumption is 3kw as shown in figure 14 and 15. I can easily use the power of the solar to operate the home and battery with the 9-level flying capacitor multi-level inverter.

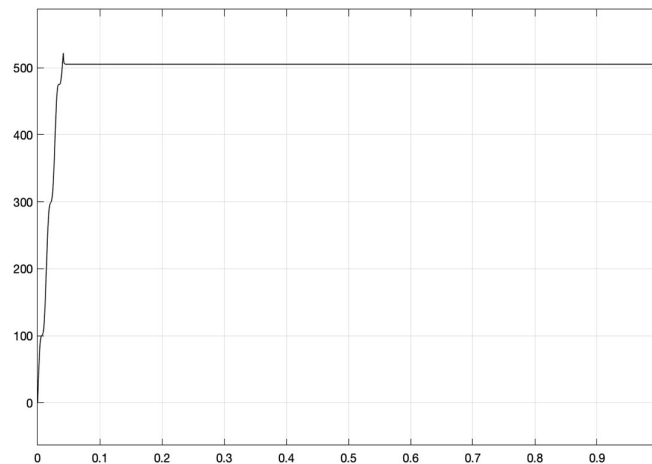


Figure 5. output voltage from the panel.(Voltage AndTime)

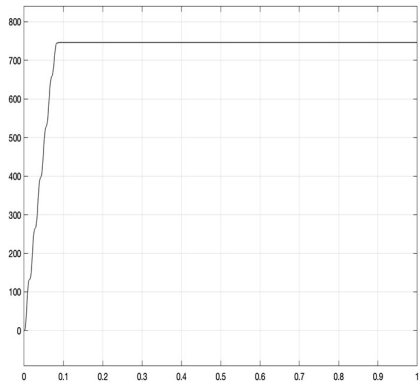


Figure 6. Boosted voltage.(Voltage and Time)

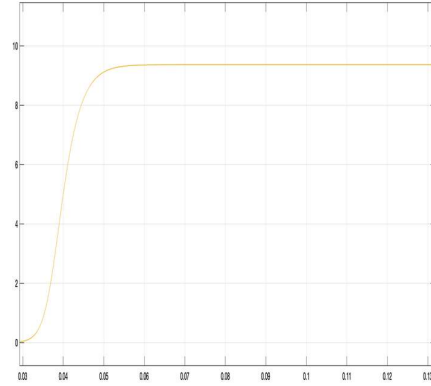


Figure 7. Current from the solar system.(Amp and Time)

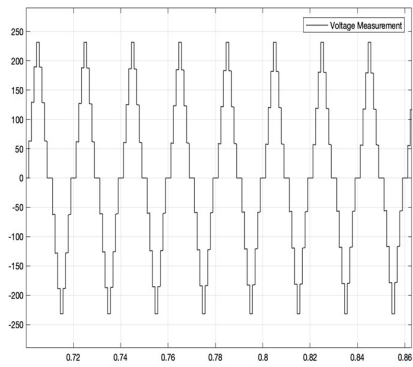


Figure 8: AC output (Voltage And Time)

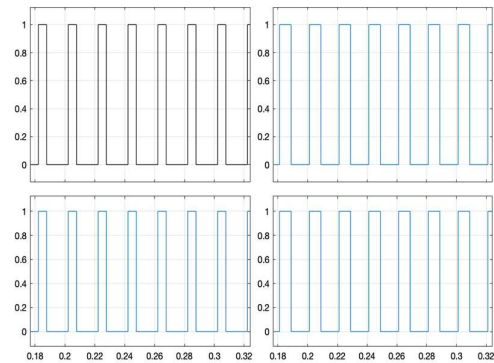


Figure 09 .Switching Pulse of S1, S2, S3, S4 from the inverter.

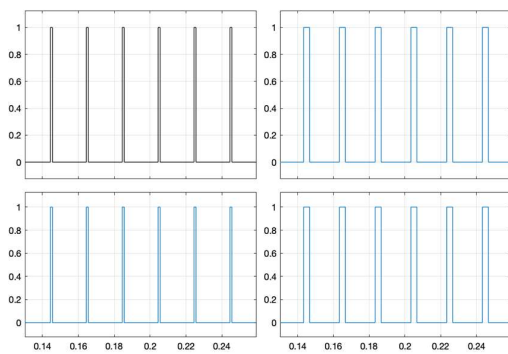


Figure 10. Switching Pulse S5, S6, S7, S8 from the inverter

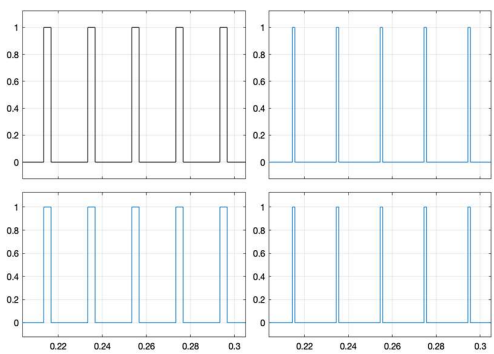


Figure 11. Switching Pulse S9,S10,S11,S12 from the inverter

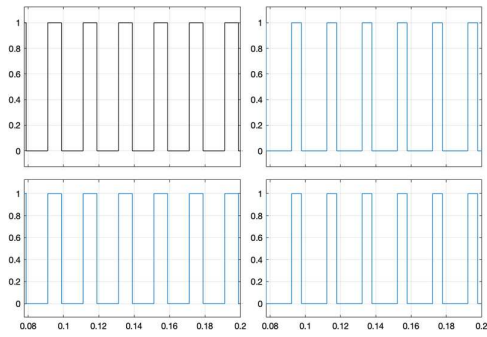


Figure 12. Switching Pulse S13, S14, S15, S16. from the inverter

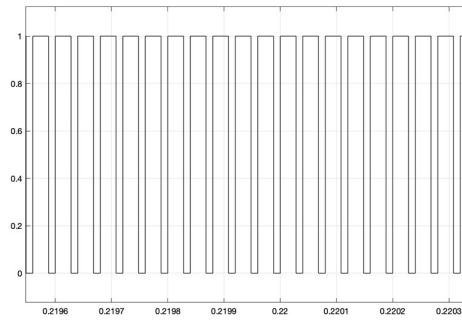


Figure 13. Switching pulse for dc-dc booster

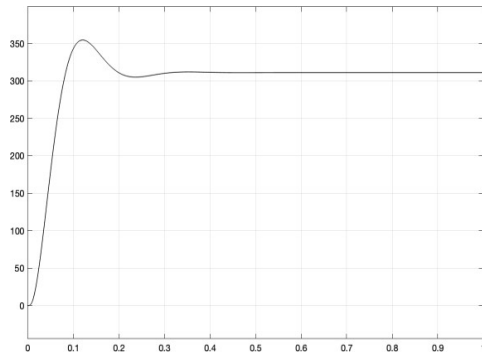


Figure 14. Load from the battery

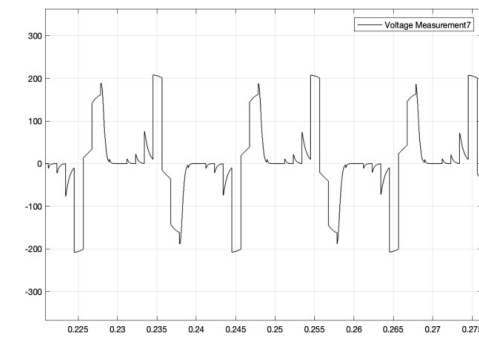


Figure 15. load from the home

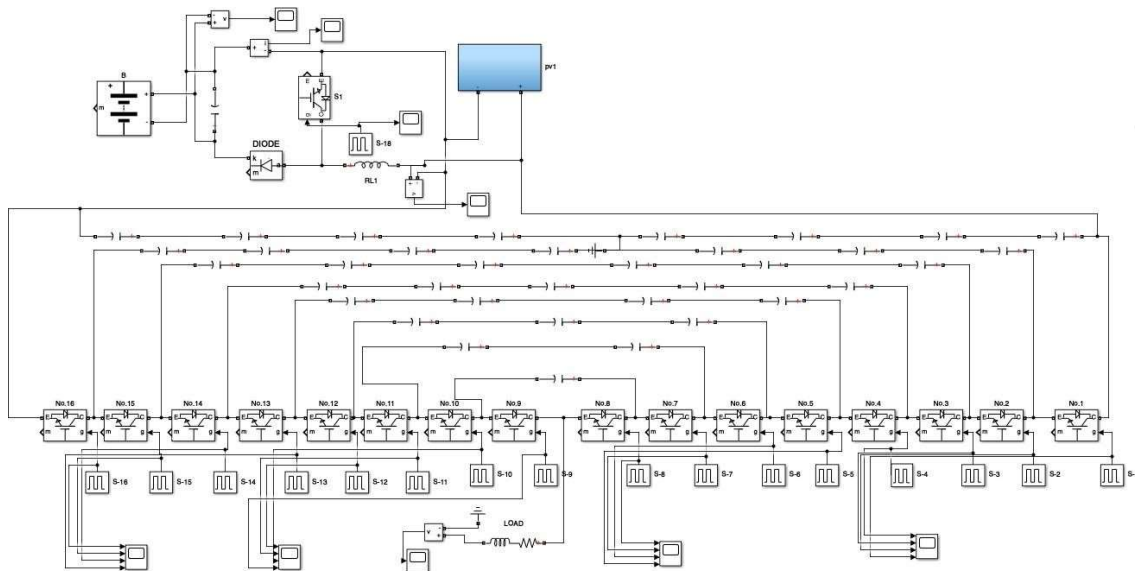


Figure 16: Simulation of the 9-level flying capacitor multilevel inverter.

In Figures, 09 to 12 Switching Pulse of S1 to S16 switches is shown in Graph. And switching pulse of the dc-dc boost converter is also shown in figure 13.

7. Conclusion

Analysis of a 9-level flying capacitor multilevel inverter is proposed in this paper. The solar panel system, EV and the inverter is connected in system. We can use this inverter for renewable energy. The simulation of this inverter was carried out. Supplied voltage from the 6.6kw solar system and the requirement of the house is 2kw is fulfilled. Also ev battery can be charged from this. We get the 9-level output from the inverter. This 9-level flying capacitor multilevel inverter was successfully done with the solar panel and EV Battery.

REFERENCES

- [1] Mohd Rizwan, Suvarna labade "A Review Paper on Electricity Generation from Solar Energy" *International Journal for Research in Applied Science & Engineering Technology Volume 5 Issue IX, September (2017)*.
- [2] C. R. Balamurugan "A Review of various multilevel inverter topologies" *global journals of advanced research vol-2, pp,142-153 (2015)*.
- [3] Nitin pawar, Vijaykumar tayal "Design of Flying Capacitor Multilevel Inverter for Solar Energy Applications" *E3S Web of Conferences ICMED (2020)*.
- [4] aanaya sinh, Shubham Sanjay "Design and Analysis of a Solar-Powered Electric Vehicle Charging Station" *MDPI (2021)*.
- [5] Stephen Watkins, l. zhang "Modelling and control of a flying-capacitor inverter" *Conference European Power Electronics Conf. January (2001)*.
- [6] Sayli Khadse "5-Level Single Phase Flying Capacitor Multilevel Inverter" *International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 02 | (2017)*.
- [7] Kamran zeb "A Comprehensive Review of DC-DC Converter Topologies and Modulation Strategies with Recent Advances in Solar Photovoltaic Systems" *Research gate (2019)*.