



NINE LEVEL CURRENT SOURCE INVERTER WITH SOLAR PV

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Abstract:

Multi-level current source using main inverter and auxiliary inductor cell is sufficient to the industrial engines because it generate high power. The present inverter consist of a basic H-bridge current source inverter working as a main inverter generates a multilevel current waveform in joining with two inductor cells connected in parallel as auxiliary circuits. The inductor cells work by generating the intermediate level of the multilevel current waveform with no additional external dc-power sources. This topology is done using Renewable energy by Depending on the solar cell as a dc source. A nine level PWM inverter configuration, with solar PV source will discuss in this paper.

KeyWords: Multilevel Current Source Inverter, Solar PV & THD

1. Introduction:

The inductor cell in five level current source inverter work by generating the intermediate level of the multilevel current waveform with no additional external dc-power sources [1]. Increasing the levels has many advantages including that the output current and power increase with number of levels [2]-[3]. The harmonic content decreases as the number of levels increases and filtering requirements are reduced. The only disadvantage of the increasing levels is that it required a huge amount of semiconductor switches. Semiconductor cost is considerably increased. Semiconductor added requires associated gate drive circuitry and adds further complication.

Multilevel inverters have the capability to deliver higher output power with lower dv/dt or lower di/dt and with less-distorted output waveforms, resulting in reduction of electromagnetic interference (EMI) noise and size of an output filter [4]-[5]. In distributed power generation application, as most renewable energy sources, such as photovoltaic systems, deliver dc power; the generated power must be converted to ac power [6]-[7].

Renewable energy is a form of energy, which comes directly from natural resources such as sunlight, wind, rain, tides and geothermal heat. It does not have a limited supply and thus can be used again and again. Further, it will not get exhausted like non-renewable sources such as coal, oil and gas [8]. Solar photovoltaic is a powerful source of energy that can be used to heat, cool, and light our homes.

2. Inverter Description:

A multilevel structure with more than five levels can significantly reduce the harmonic content, results reduction in di/dt then reduced switching stresses on devices, smaller size of filter capacitor [9]. When N= 2, (equation (1)) we get ninelevel and the output current Of nine level Current source inverter, +I, +3I/4, +I/2, +I/4, 0, -I/4, -I/2, -3I/4, and -I .

Increasing levels depending on the relationship between the level number of output current waveform (M) and the number of inductor cells (N) [1].

$$M = 2^{(N+1)} + 1 \dots\dots\dots (1)$$

When N= 2, We get nine level output current waveform

And Nth inductor cell ILc (i) is expressed as

$$ILc(i) = \frac{I}{2^i} \dots\dots (2) \quad \text{Where } i=1, 2, 3\dots N$$

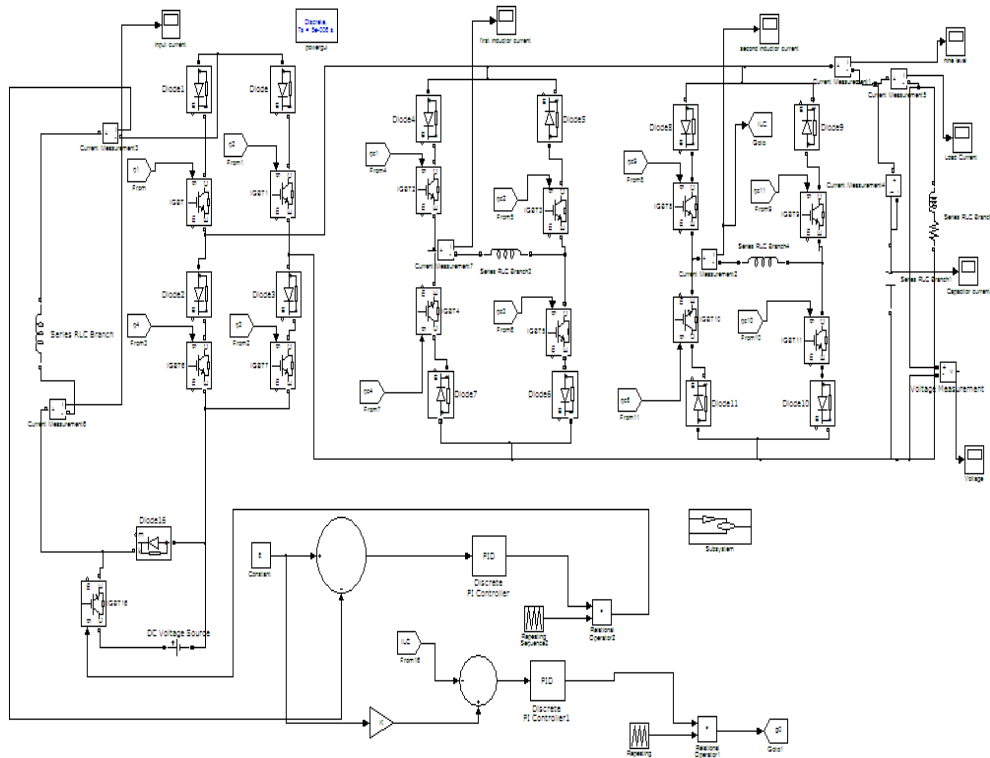


Figure 1: Matlab/Simulink Model of Nine level CSI

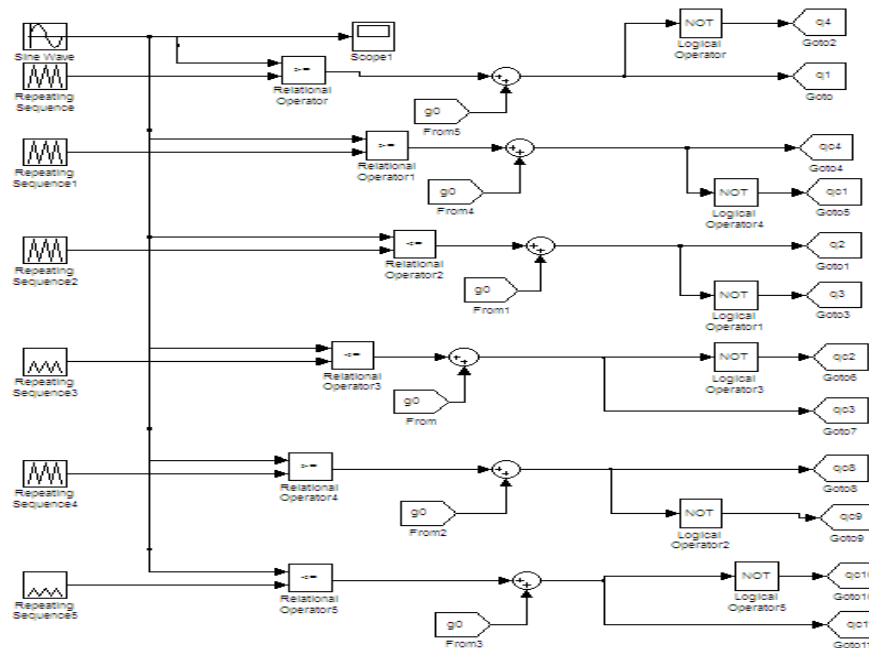


Figure 2: Subsystem of Nine level CSI

3. Simple Working of a Solar Cell:

A solar cell is made of a semiconductor and most of it today are made of crystalline silicon [8]. A solar cell generally has two layers. First layer has the silicon/ boron semiconductor and is known as the p- type. Second layer is the silicon/ phosphorus semiconductor and is known as then- type. When the two layers p and n type meet is known the p-n junction.

Metal electrodes are attached to the front and back of the cell. The electrode is in the form of a metal grid with fingers. It allows the sunlight to pass through it. An

antireflection coating is used to decrease the amount of reflection. A typical cell develops a voltage of 0.5 volts and current density of 20-40 milliamperes. To get more voltage and current, individual cells are joined in series and parallel fashion. This takes the shape of a solar module. In turn, a number of modules are joined together to form a solar array.

When we bring p-type and n-type material together, a diffusion occurs on the surface between them. Electrons start to diffuse from n-type to p-type. Similarly, holes diffuse from p-type region to n-type region. This diffusion creates an electron-hole free region in a very short distance at the interface region. This thin layer is called the depletion region [10].

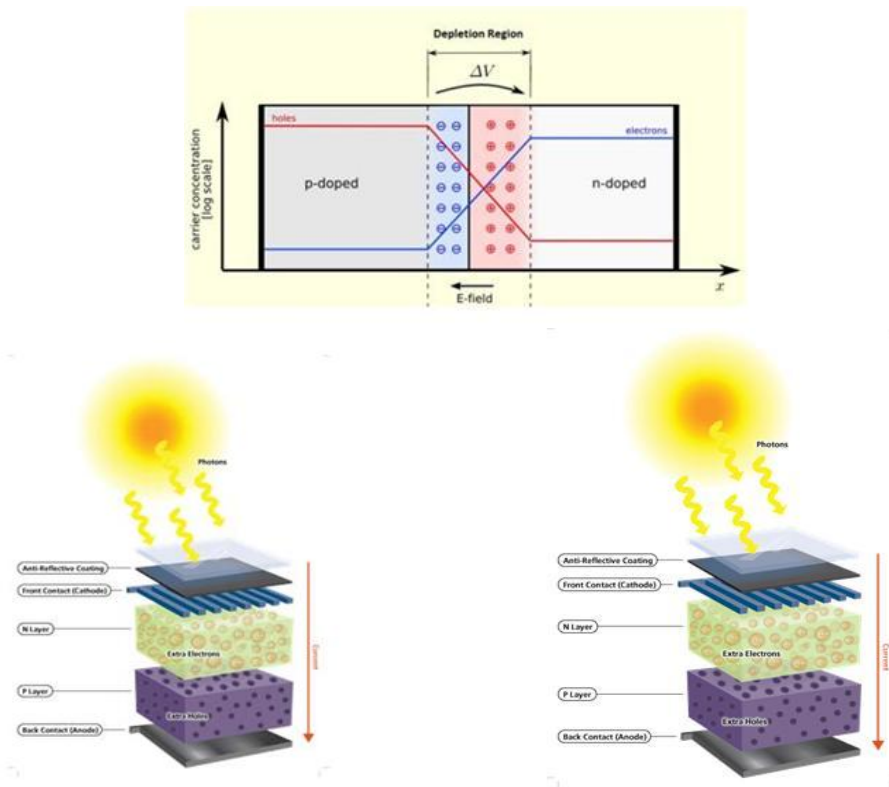


Figure 3: Solar Cell Construction

You can see the diffusion in depletion in figure. Blue line indicates the electron concentration while red line indicates hole concentration through semiconductor material. As you see there is an electric field from the n-side to the p-side of the depletion region. Since the electrons are negative charges this electric field applies a force to an electron entering the depletion region. Any electron generated by sun light in the vicinity of the depletion region may pass to the n-side of the junction very easily. If we connect a wire or any load between the ends of n-type and p-type region with metal contacts, this electron will flow to the p-type through this external load. So we need an external energy to create this current: something should energize the electrons in the p-type region to enter depletion region. Solar radiation is an excellent energy source to do this job.

The solar cell type explained above is the example of first generation, wafer based Crystal Silicon solar cells. There are some differences in the structure of other solar cell types. But the basic principle is the same: some kind of p-n junction (or similar

potential energy profile) has to be used to convert the solar radiation to electrical energy. Different photovoltaic cell types are discussed.

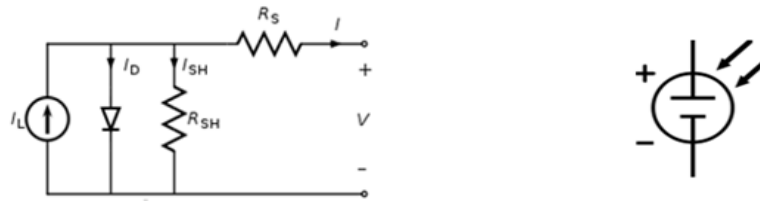


Figure 4: Equivalent circuit of a solar cell

To understand the electronic behavior of a solar cell, it is useful to create a model which is electrically equivalent, and is based on discrete electrical components whose behavior is well known. An ideal solar cell may be modeled by a current source in parallel with a diode; in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model (figure 4) The resulting equivalent circuit of a solar cell is shown on the left and on the right, is the schematic representation of a solar cell for use in circuit diagrams.

4. Advantages and Limitations of Solar PV Systems:

It offers the following few advantages:-

- ✓ Sunshine is totally free (there is no fuel cost).
- ✓ Produce no harmful gases (it is totally safe for our environment).
- ✓ Last longer (these system work well).
- ✓ Running cost is very low (very low maintenance is needed).
- ✓ Very suitable for remote area lighting (improve the quality of life in such areas)

However it has some limitations like

- ✓ High cost of the products/ systems.
- ✓ Depends on the sunshine which may or may not be present always.
- ✓ Depends on battery storage to run any load at night.

5. Nine Level CSI with Solar PV:

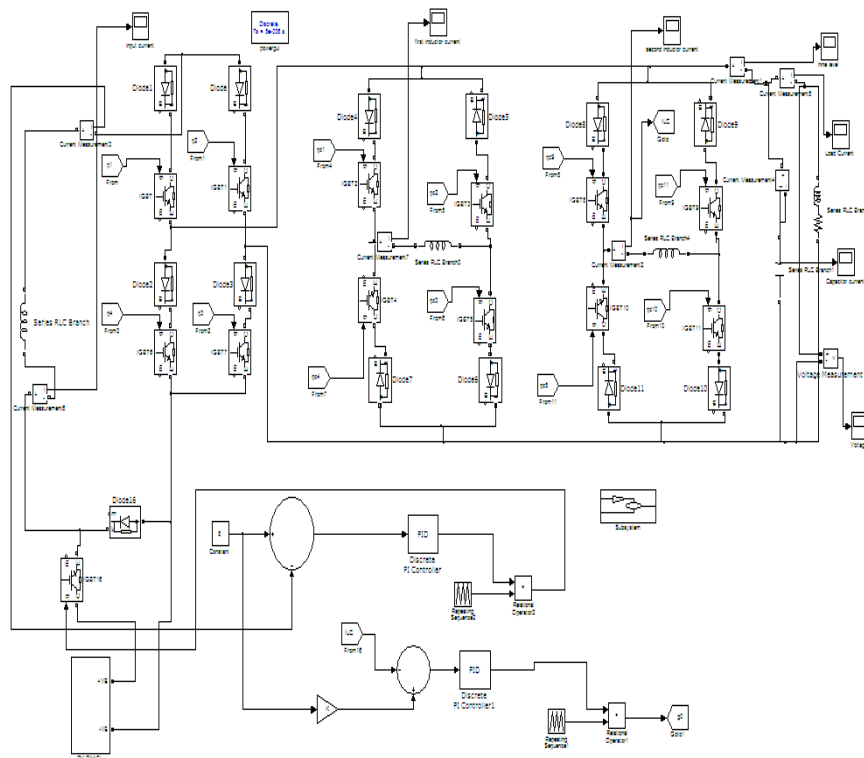


Figure 5: Matlab/Simulink Model of Nine level CSI with PV source

6. Subsystem of the Solar PV:

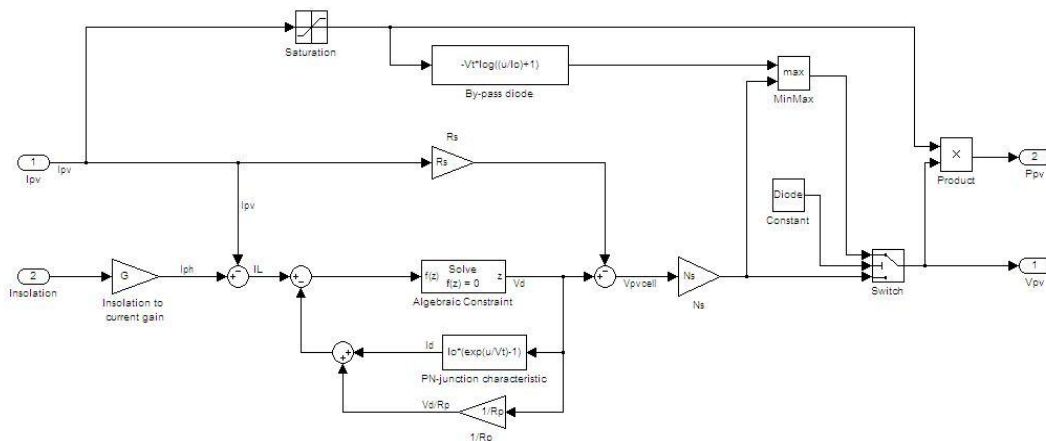


Figure 6: Subsystem of the solar PV

7. Ratings of the Nine Level Inverter:

Smoothing (Li) and inductor cell(Lc)	=	1mH and 5mH
Inverter switching frequency	=	22KHz
Filter capacitor Cf	=	5µf
Load	=	R=8Ω, L=1.2 mH
Output current frequency	=	50 Hz

8. Ratings of the Solar PV:

Short circuit current	=	4.9 A
Open circuit voltage	=	21 V
Current at P _{max}	=	4.4 A
Voltage at P _{max}	=	17V
No. of cells in series in each module	=	35
No. of PV modules connected in series	=	8
No. of cells in parallel in each module	=	26

9. Program for the Solar PV:

```

Voc=21;
Isc=4.9;
Vmpc=17;
Impc=4.4;
Vr=17;
Ir=4.4;
Ns=round(Voc/0.61);
Np=round(Isc/0.19);
Vt=26e-3;
G=Isc/1000;
Vmpcc=Vr/Ns;
Vocc=Voc/Ns;
Rmpp=Vmpcc/Ir;
Rp=100*Vocc/Isc;
Vdm=Vocc;
fori=1:10
Idm=Isc-Ir-Vdm/Rp;
Io=(Isc-Vocc/Rp)/(exp(Vocc/Vt)-1);
Vdm=Vt*log(Idm/Io+1);
    
```

```
Rs=(Vdm-Vmpcc)/Ir;  
Rd=(Rmpp-Rs)*Rp/(Rp-Rmpp+Rs);  
Idm=Vt/Rd;  
Rp=Vdm/(Isc-Ir-Idm);  
End
```

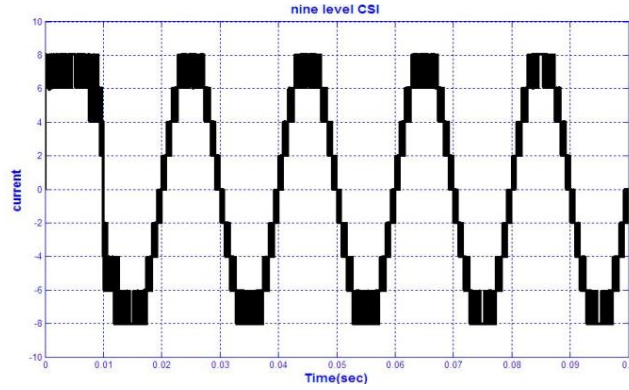


Figure 7: Output of Nine level CSI with solar PV source

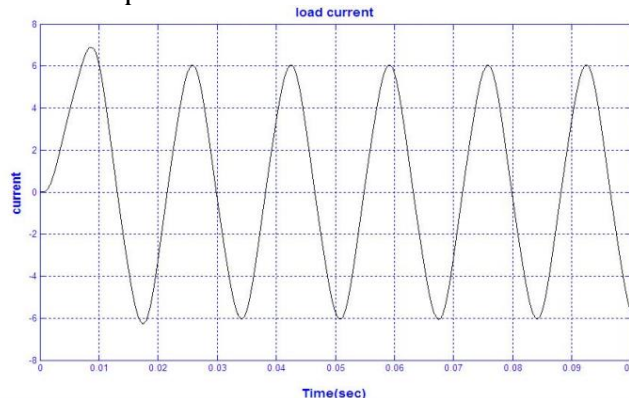


Figure 8: Output waveform of current with RL load

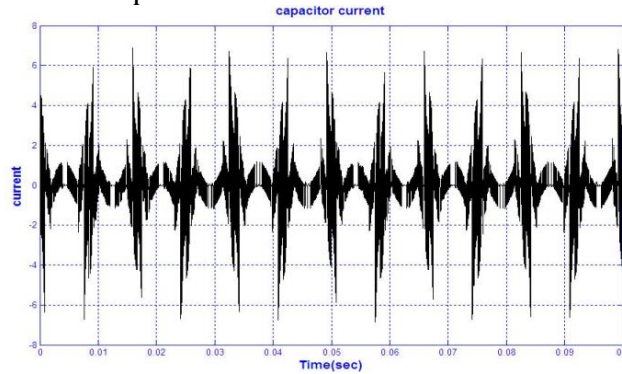


Figure 9: Capacitor current Output



Figure 10: Nine level Voltage Output

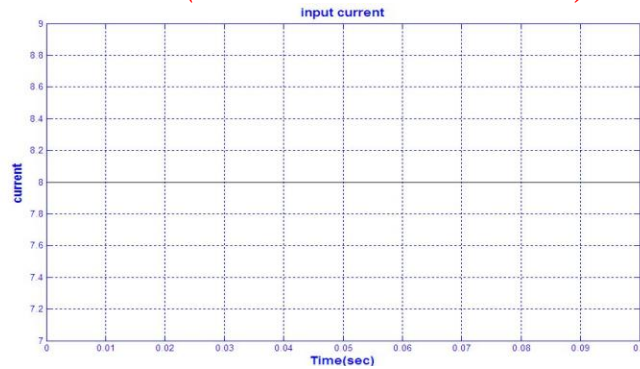


Figure 11: input current output

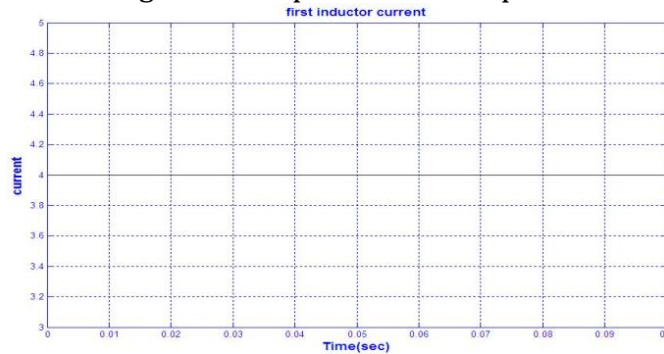


Figure 12: First inductor current output

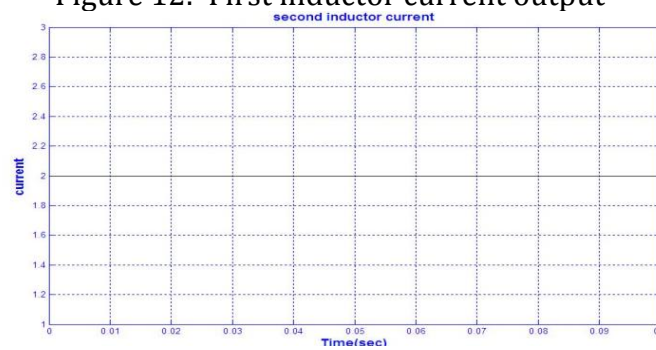


Figure 13: Second inductor cell current output

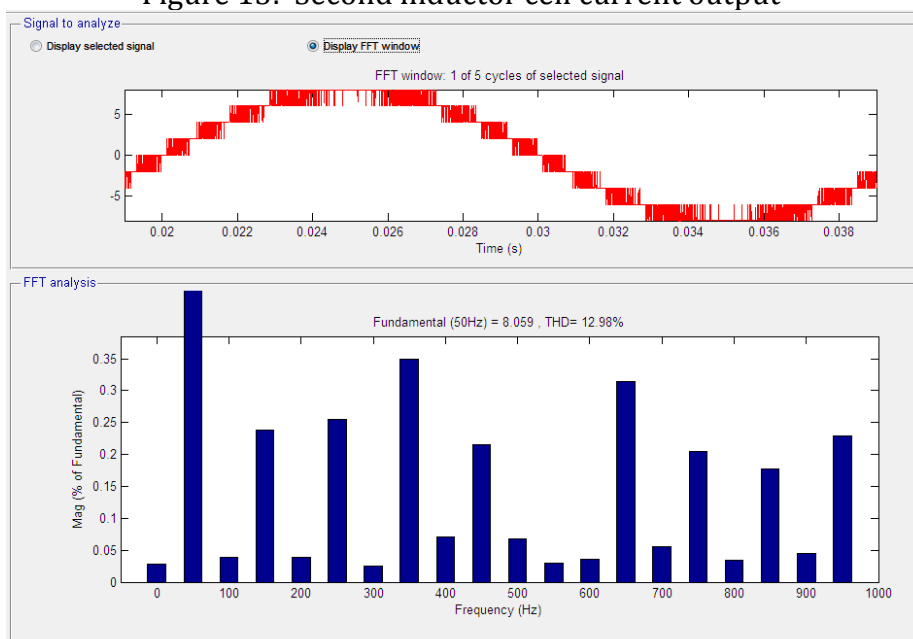


Figure 14: FFT Analysis for Nine level current

10. Comparison between Five and Nine level CSI:

Topology	Five level	Nine level
No. of switches	Eight	Twelve
No. of diodes	Eight	Twelve
THD	26.91 %	12.98 %

11. Conclusion:

Nine level current source inverter is done using Renewable energy by Depending on the solar cell as a dc source. This topology provide us less total harmonic distortion, increasing current level in the output (sufficient for high power), reduction in di/dt then reduced switching stresses on devices, smaller size of filter capacitor, Electromagnetic interference is low. Even though, more levels needs more switches, more cost, more complicate.

12. References:

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