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Interleaved Boost Converter with Maximum Power Point Tracking Algorithm for Photovoltaic System

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***Abstract* :- Renewable energy resources play an important role in replacing conventional fossil fuel energy resources. photovoltaic energy (PV) is one of the very promising renewable energy resources which grew rapidly in the past few years, the pv energy suffers one of the major problem is nothing but variation of the operating conditions of the array, due to this the voltage at which maximum power obtained from solar panel also changes. To overcome this draw back and continuously track maximum available power from solar panel, by using the mppt control techniques. This mppt control techniques are implemented by using different mppt algorithms.**

The output power of solar panel is step up by using interleaved boost converter .This converter having more benefits compare to other conventional converters. By using this converter the current ripple is reduced and the overall output voltage gain increases. Here mainly two algorithms like p&o and fuzzy logic control algorithms are implemented, when used to give pulses to the switches for the interleaved boost converter. The output of this converter is given as input to the loads like R load and AC loads. The entire system has been modeled and simulated using MATLAB/Simulink software.

Keywords:- IBC,PHOTO VOLTALIC PANEL,MPPT, MATLAB SIMULATION.

1. INTRODUCTION

Nowadays, Renewable energy is gaining popularity worldwide due to the increasing price of fossil fuels as well as the risk of climate change. At present, there have also been some developments in this area like enhancement in efficiency and reducing prices. All of these developments have enhanced the demand for cleaner and more sustainable techniques of electrical power.
Renewable energy is a term used to refer to forms of energy that are naturally obtained from the environment and from sources that can be replenished naturally. These include solar energy, wind energy, geothermal energy, hydropower, and biomass. The term renewable energy should not be confused with alternative energy, which describes sources of energy outside the regular forms like gasoline that are considered more environment-friendly or less harmful.

2. PHOTOVOLTAIC CELL AND THEIR CHARACTERISTICS

Solar cells are the basic components of photovoltaic panels. Most are made from silicon even though other materials are also used. Solar cells take advantage of the photoelectric effect: the ability of some semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to create an electrical current by an appropriate design of the structure of the solar cell.

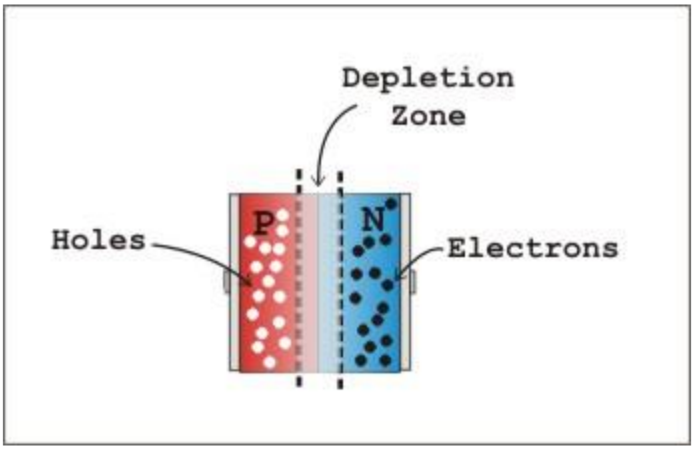

Fig 1: Solar cell

2.1 Equivalent circuit of a solar cell:

The solar cell can be represented by the electrical model shown in Fig 2. Its current-voltage characteristic is expressed by the following equation 1

$$I = IL - I0(e^{q\frac{(V-IRS)}{AKT}}-1) - \frac{V-IRS}{RSH} \quad (1)$$

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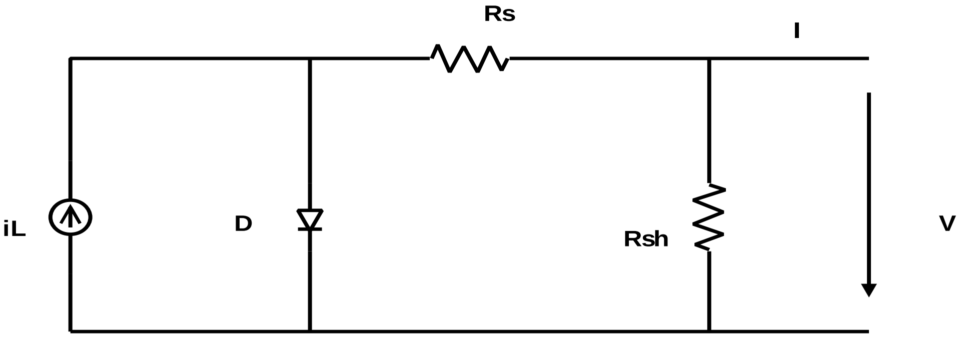

Fig 2: Equivalent circuit of a solar cell.

where I and V are the solar cell output current and voltage respectively, I0 is the dark saturation current, q is the charge of an electron, A is the diode quality (ideality) factor, k is the Boltzmann constant, T is the absolute temperature and RS and RSH are the series and shunt resistances of the solar cell. RS is the resistance offered by the contacts and the bulk semiconductor material of the solar cell. The origin of the shunt resistance RSH is more difficult to explain. It is related to the non ideal nature of the p–n junction and the presence of impurities near the edges of the cell that provide a short-circuit path around the junction. In an ideal case RS would be zero and RSH infinite. However, this ideal scenario is not possible and manufacturers try to minimize the effect of both resistances to improve their products.
Sometimes, to simplify the model, as in the effect of the shunt resistance is not considered, i.e. R_{SH} is infinite, so the last term in is neglected.
A PV panel is composed of many solar cells, which are connected in series and parallel so the output current and voltage of the PV panel are high enough to the requirements of the grid or equipment. Taking into account the simplification mentioned above, the output current-voltage characteristic of a PV panel is expressed by equation 2, where n_p and n_s are the number of solar cells in parallel and series respectively.

$$I = npIL - npI0\ (e^{q\frac{(V-IRS)}{AKTns}} - 1) \qquad (2)$$

2.2 Open circuit voltage, short circuit current and maximum power point:

Two important points of the current-voltage characteristic must be pointed out: the open circuit voltage V_{OC} and the short circuit current I_{SC}. At both points the power generated is zero. V_{OC} can be approximated from equation 1, when the output current of the cell is zero, i.e. I=0 and the shunt resistance R_{SH} is neglected. It is represented by equation 3. The short circuit current I_{SC} is the current at V = 0 and is approximately equal to the light generated current I_L as shown in equation 4.

$$Voc = \frac{AKT}{q}\ln\left(\frac{IL}{I0}+1\right) \qquad (3)$$

$$Isc = IL \qquad (4)$$

The maximum power is generated by the solar cell at a point of the current-voltage characteristic where the product VI is maximum. This point is known as the MPP and is unique, as can be seen in Figure 3.

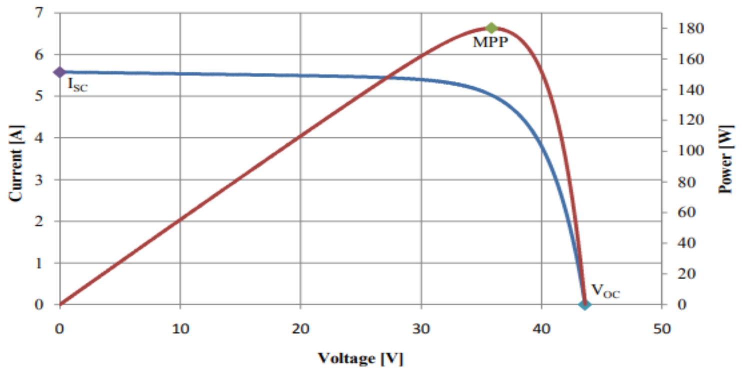

Fig 3: Important points in the characteristic curves of a solar panel

3. INTERLEAVED BOOST CONVERTER:

The schematic diagram of the interleaved boost converter is as shown in Fig 4. The interleaved boost Converter consists of two boost converters connected in parallel controlled by phase-shifted switching function. The switching operation of the interleaved boost converter shown in Fig 5. In this application we have chosen single phase interleaved boost converter, so the phase shift between each switch is 180 As the number of converters connected parallel increases the phase shift angle decreases.

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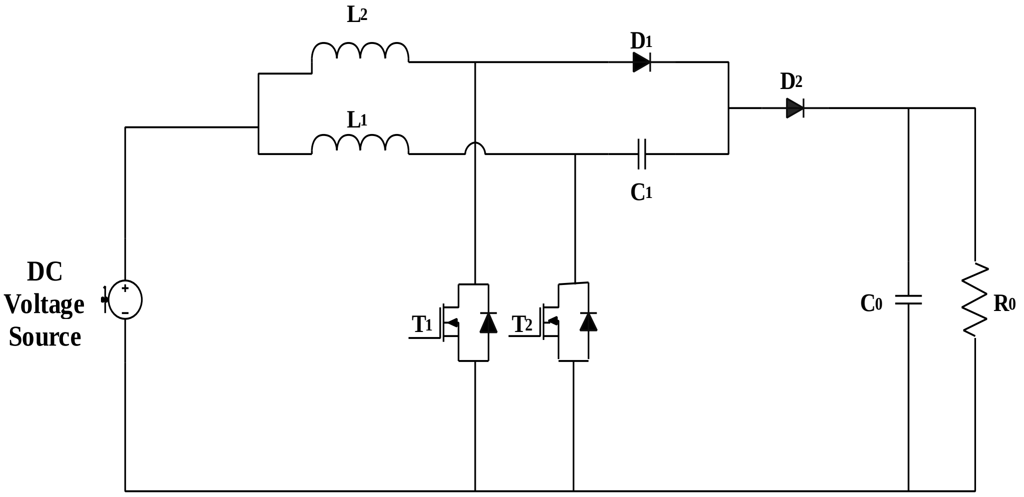

Fig 4: schematic diagram of interleaved boost converter

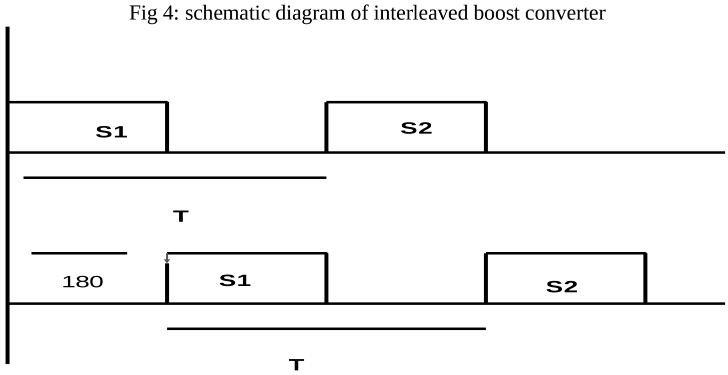

Fig 5: Timing diagram of Control Signal

3.1 Principle of operation of interleaved boost converter

The inductorsL1 and L2 are having the same inductance value which is equivalent to L for simple calculations. Duty cycle of S1 was denoted by D1 like foe S2 as D2.The duty cycle values of both witches were equivalent to D. The operating mode of the converter can be explained as:

- Stage I: Currents through inductor L1 starts to rise while being discharged through L2 when switch S1 is closed and S2 is opened at time T0.
- Stage II: Currents through inductor L1 starts to discharge also being discharged through L2 through load when switch S1 and S2 are opened at time T1.
- Stage III: Currents through inductor L2 starts to rise while being discharged through L1 when switch S2 is closed and S1 is opened at time T2.
- Stage IV: Currents through inductor L1 starts to discharge also being discharged through L2 through load when switch S1 and S2 are opened at time T3 same as like in mode II. The cycle then repeats.

Mode 1:T1 ON

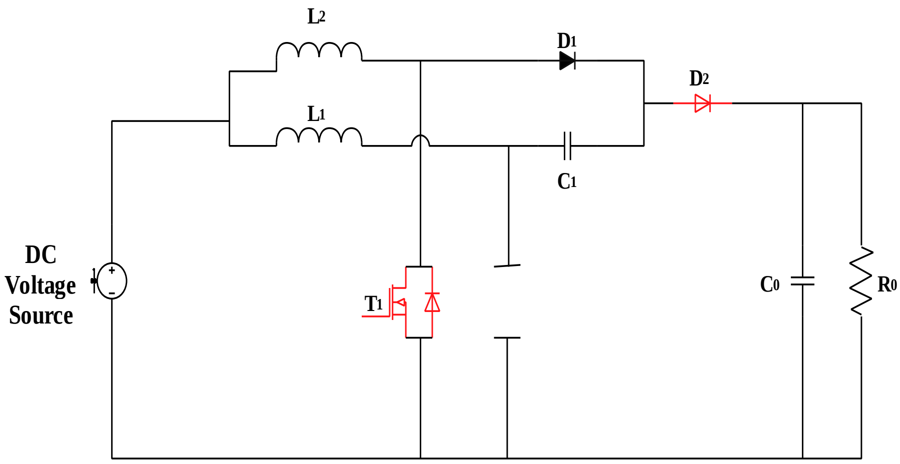

Fig 6: Mode 1

For inductor L1

$$Vin = L1\,\frac{dI1}{dt} \qquad (5)$$

For inductor L2

$$Vin - Vo = L2\frac{dI2}{dt} \qquad (6)$$

Assume $\Delta I = I2 - I1$

$$Vin = L1\frac{\Delta I}{t1} \qquad (7)$$

$$t1 = L1\frac{\Delta I}{Vni} \qquad (8)$$

Mode 2: During T1 off & T2ON

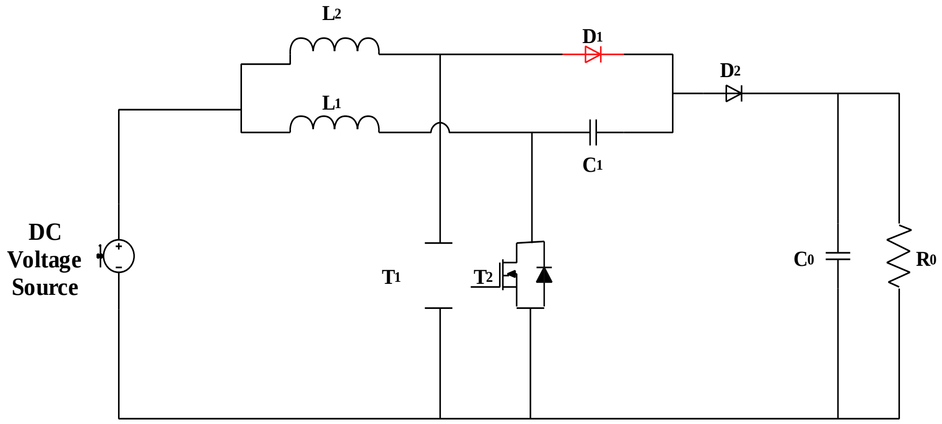

Fig 7: Mode 2

For inductor L1

$$Vin - Vo = -L1\frac{dI}{dt} \qquad (9)$$

$$t2 = \frac{\Delta IL1}{Vo-Vin} \qquad (10)$$

Substitute t1=DTs and t2 = (1-D) Ts

$$\Delta I = \frac{Vo-Vin*t2}{L} \qquad (11)$$

Substitute t1=DTs and t2 = (1-D) Ts

$$= \frac{Vo-Vin*t2}{L}$$

$$= \frac{Vin*DTs}{L} = \frac{(Vo-Vin)}{L}\,(1-D)Ts \qquad (12)$$

Total time period

$$T = t1 + t2 = \frac{\Delta Il}{Vin} + \frac{\Delta Il}{Vo-Vin} \qquad (13)$$

$$T = \frac{\Delta Il\ Vo}{Vin(Vo-Vin)}$$

Peak to peak ripple current

$$T = \frac{1}{f}$$

$$\Delta I = \frac{Vin(Vo - Vin)}{fLvo} \quad (14)$$

Waveforms:

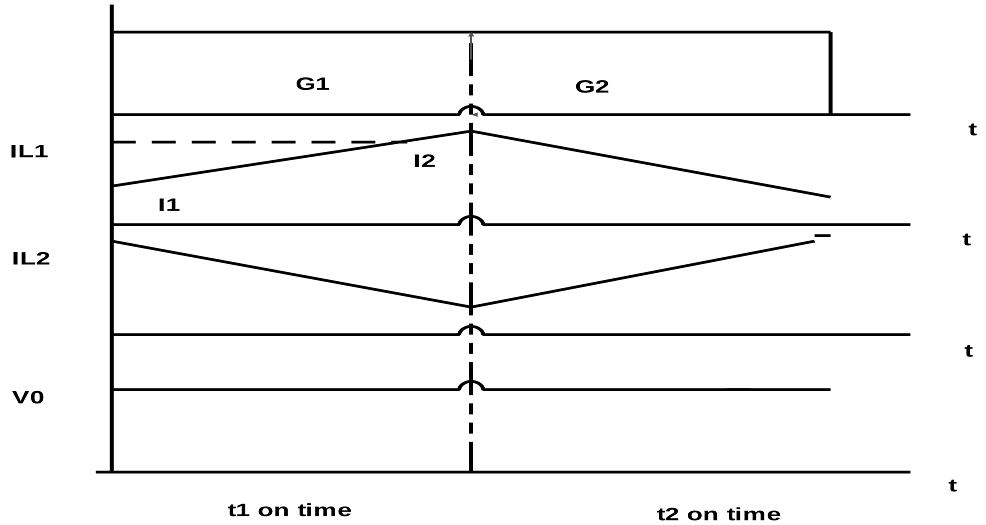

Fig 8: Operating wave form

For output capacitor

$$\Delta Vc = Vc - Vc(t-0) = \frac{1}{C}\int_0^{t1} Icdt \quad (15)$$

$$\Delta Vc = \frac{It1}{C} \quad (16)$$

Substitute

$$t1 = \frac{Vo - Vin}{Vo * f} \quad (17)$$

$$\Delta Vc = \frac{Iok}{fc} \quad (18)$$

4. MAXIMUM POWER POINT TRACKING:

4.1 Introduction:

Maximum power point tracking (MPPT) was first introduced in the 1980s and inspired the solar industry to find solutions to module inefficiencies. One of the largest issues with solar power continues to be the inefficiencies of the panels, which usually hovers below 25%. Maximum power point tracking was designed to counteract the inefficiencies of these panels and continue to make them more affordable and powerful. MPPT does not have any correlation to mechanical trackers, which can frequently be used in combination with solar modules.

4.2. Perturb & Observe method:

Perturb and observe has been and currently is the most widespread MPPT algorithm. The implementation of the algorithm is relatively inexpensive while being very robust and effective. The idea behind P&O is essentially like playing a game of tag with the maximum power point of a solar module.

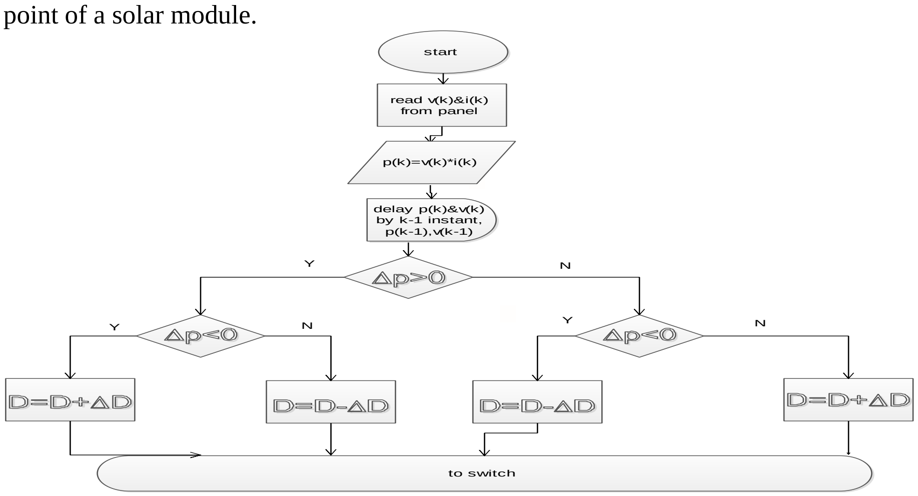

Fig:9 Flow chart P&O algorithm

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4.2.1 Fuzzy logic controller method:

FLC is composed of main three parts as shown in figure .

- Fuzzification interface
- Knowledge base and inference engine
- Defuzzification interface

4.2.2 Fuzzification Interface:

The first step towards designing a FLC is choosing appropriate inputs which will be fed to the system. These input variables should be such that, they represent the dynamical system completely. Then the function of the fuzzifier comes into picture. As discussed before, instead of using numerical variables, fuzzy logic uses linguistic variables for processing information. This function of converting these crisp sets into fuzzy sets (linguistic variables) is performed by the fuzzifier. So fuzzification is the process of translating crisp input values into fuzzy linguistic values through the use of membership functions. In other words, determining how much each discrete input value belongs to each input fuzzy set using the corresponding membership function.

4.2.3 Fuzzy Inference Engine MPPT:

Fuzzy rule base is a collection of if-then rules that contain all the information for the controlled parameters. It is set according to professional experience and the operation of the system control. The fuzzy rule algorithm includes following fuzzy control rules listed below in table 4.1.

E / CE	NB	NS	ZE	PS	PB
NB	ZE	PB	PB	PB	PB
NS	PB	PS	PS	ZE	ZE
ZE	PS	ZE	ZE	ZE	NS
PS	ZE	ZE	NS	NS	NB
PB	PB	ZE	NS	NB	ZE

Table 1: fuzzy logic control variables

5. SIMULATIONS AND RESULTS:

5.1 Simulink Model of MPPT Technique:

This chapter presents MATLAB simulations perform comparative tests between the P&O and fuzzy MPPT algorithm of PV system. Simulations also verify the functionality of MPPT with a resistive load and ac load like single phase induction motor. Some selected results are presented which show the simulation results of PV and load operating point at different irradiance and temperature levels.

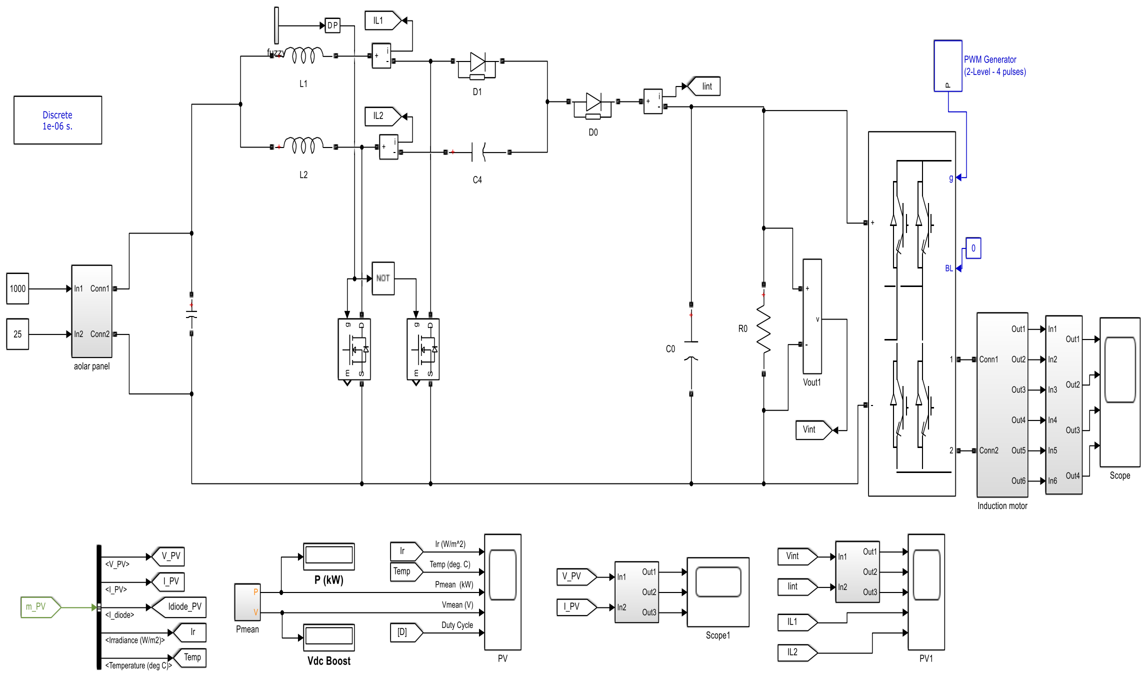

Fig 10: Simulink model of interleaved boost converter with P&O

5.2 PV array Characteristics:

Sun Power E18 305 module is modeled and simulated because a single module can be used to meet the power need of a room due to its high power rating and efficiency. parameters of manufacture's data sheets are presented in Table 2.

Parameters	Value
Maximum Power Pmax	305watts
Voltage at maximum Vmax	54.7 volts
Current at maximum power Imax	5.58amps
Open circuit voltage Voc	64.2 volts
Short circuit current Isc	5.96 amps
Temperature coefficient of Isc (ki)	0.061745
Total no. of parallel strings	66
Series connected modules per sting	5
Cells per module	96
Current at mpp Imp	5.58

Table: 5.2 .Specifications of PV Panel

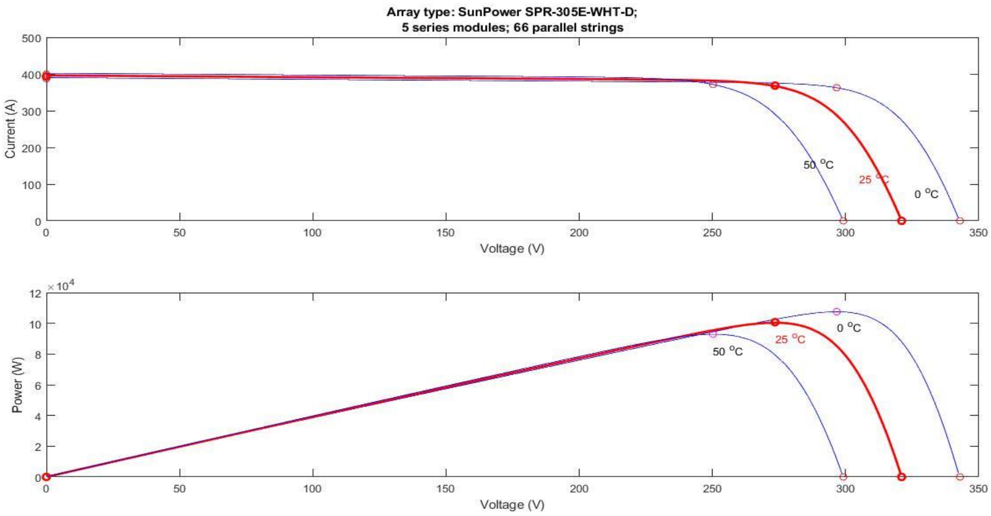

Figure 11: PV panel voltage vs current and power vs voltage characteristics

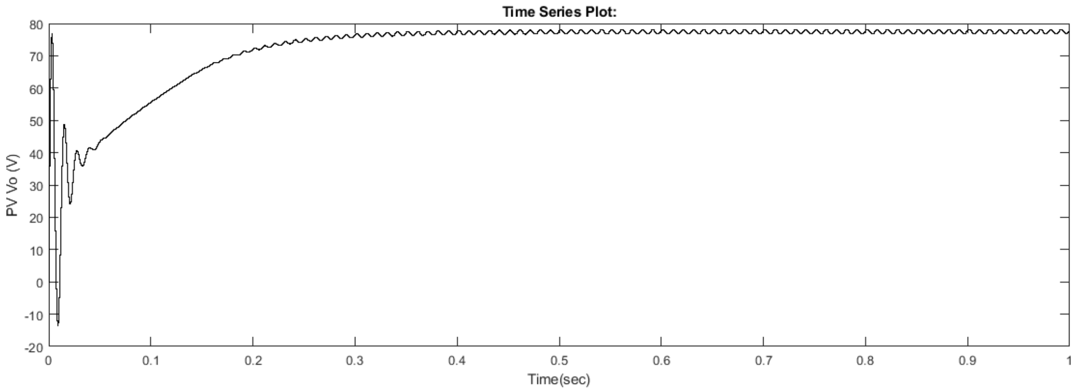

Figure12: output voltage of solar panel with mppt (p&o)

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The maximum output voltage across R load with IBC p&o algorithm is 210v is shown in figure 5.4 the output voltage of solar panel is 75v it is step-up by interleaved boost converter with p&o mppt technique.

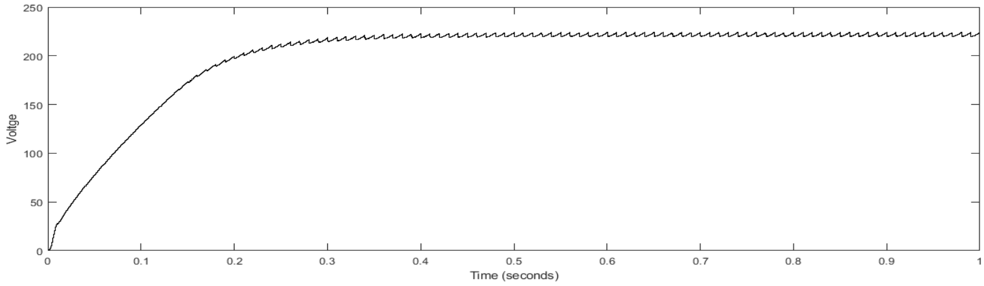

Figure 13: output voltage across R load with IBC p&o algorithm is 210v

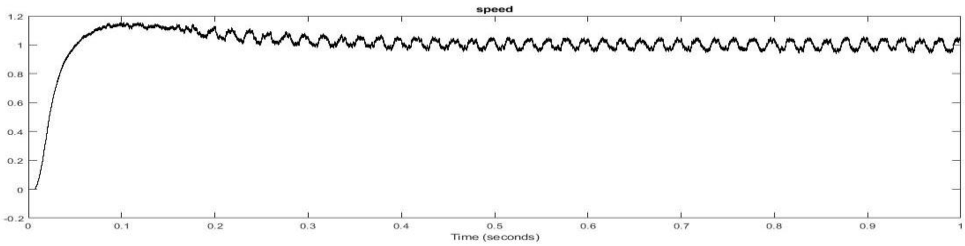

Figure14: Speed characteristics of single phase induction motor

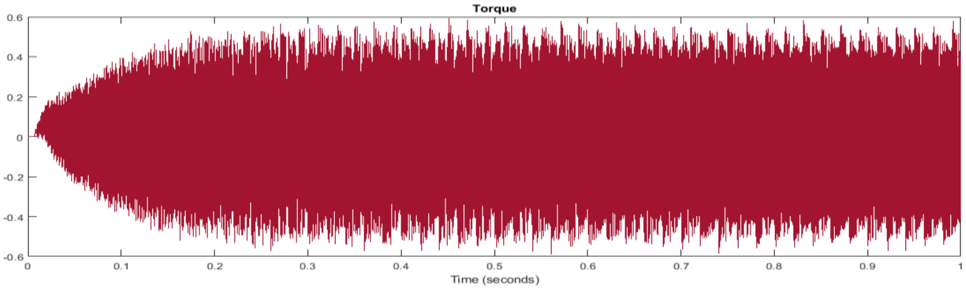

Figure 15: Torque characteristics of single phase induction motor

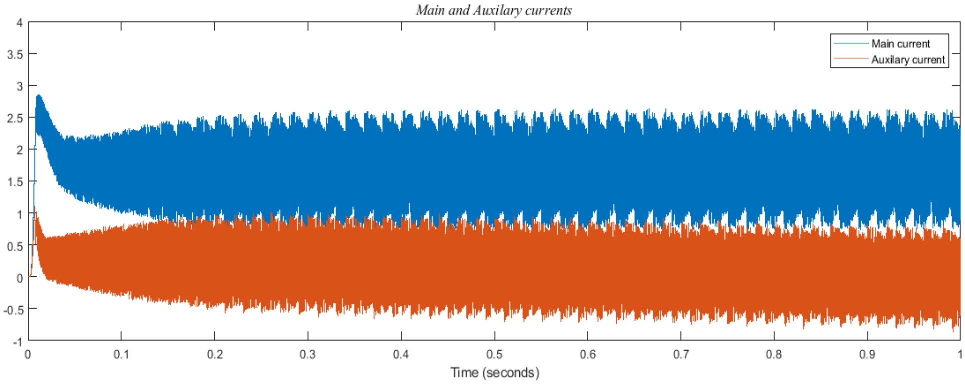

Figure16: Main and Auxiliary current characteristics of single phase induction motor

5.3 Simulation of fuzzy logic controller:

5.3.1 FLC Input for MPPT:

The fuzzy logic control system is represented in the MATLAB/Simulink software. In the MATLAB/Simulink write the “fuzzy” in the command window and the fuzzy system window will be appear in which there is a Mamdani-type system with two inputs and one output has been established. In the figure there are two inputs. The input E represents the power and the input CE represents the change in voltage of the PV generator and one output D represents the duty cycle which will generate the control signal to the converter of the PV generator.

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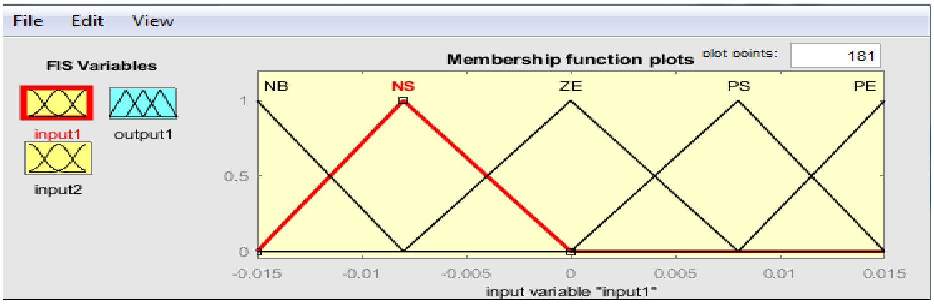

Figure 17: fuzzy logic controller input

5.3.3. Defuzzification applied for MPPT:

This operation converts the inferred fuzzy control action into a numerical value at the output by forming the union of the outputs resulting from each rule. The centroid method is used for defuzzification. Figure 18 shows member ship of output U.

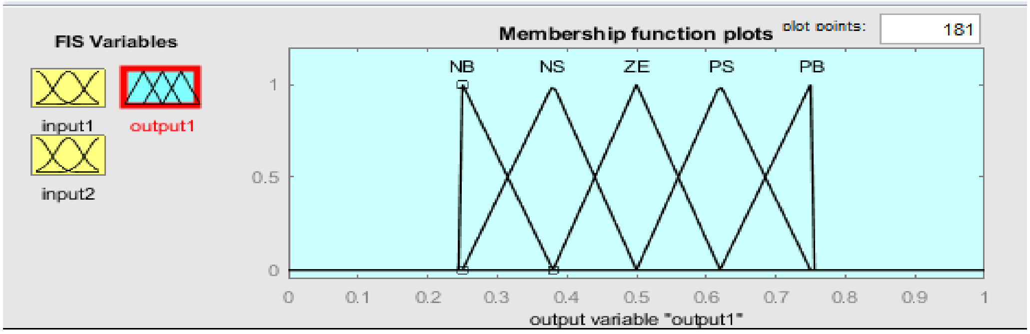

Figure18: output membership function for dutycycle

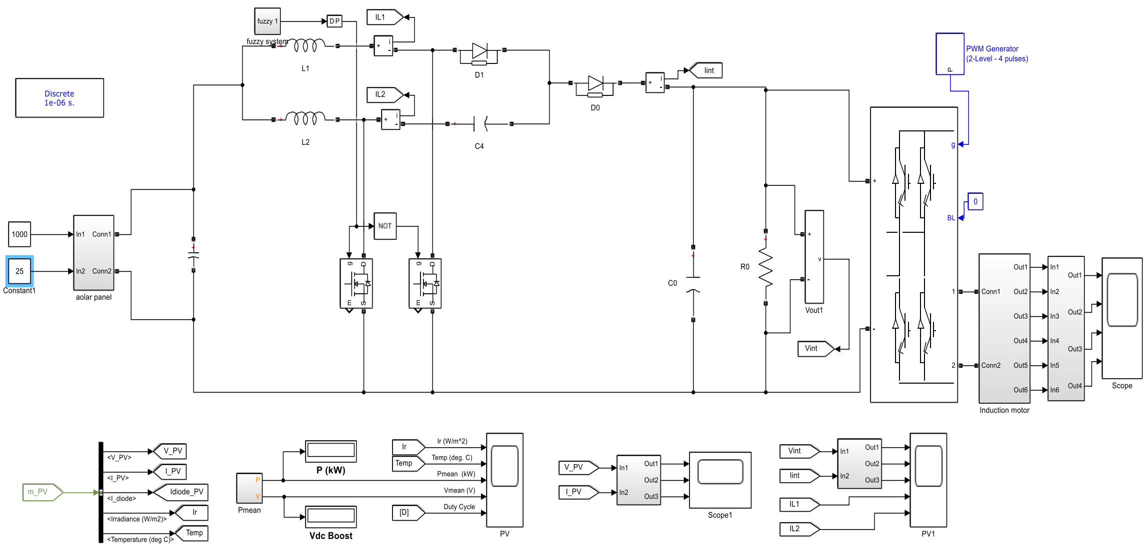

Figure19: simulink model of interleaved boost converter with fuzzy mppt

The voltage characteristics of pv panel and interleaved boost converter with fuzzy mppt technique are shown in figure 20 and 21 the of pv panel output voltage is step up by 92.4v to 465.65v compare to p&o method more amount of voltage continuously tracking at all conditions by using fuzzy method

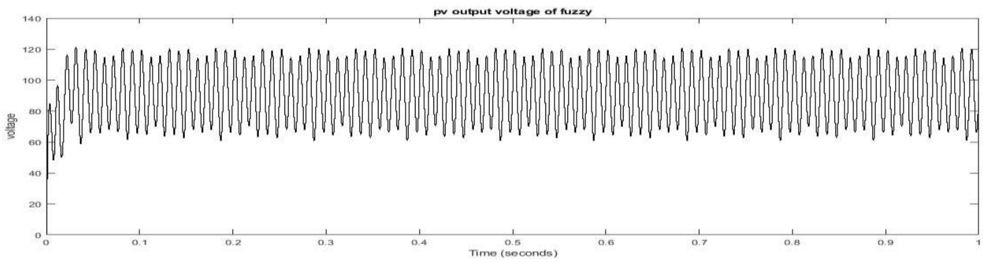

Figure 20: output voltage of pv with fuzzy mppt

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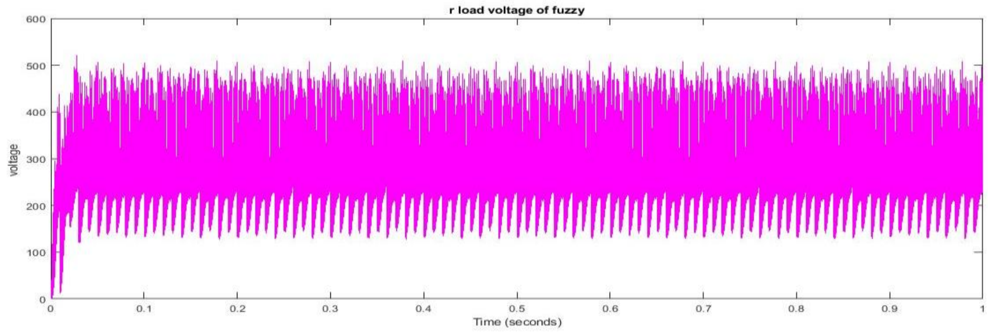

Figure 21: output voltage across R load with fuzzy mppt

The output voltage of interleaved boost converter with fuzzy mppt technique is given as input to the single phase induction motor and its speed, torque, voltage and main auxiliary currents are shown in figures bellow.

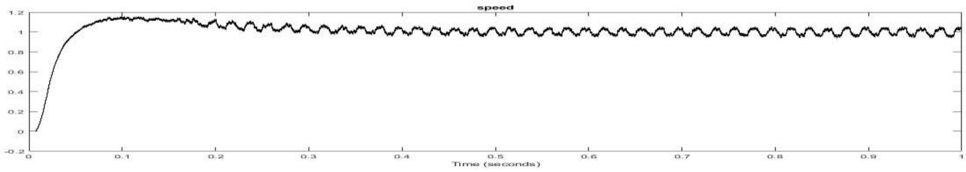

Figure 22: Speed characteristics of single phase induction motor

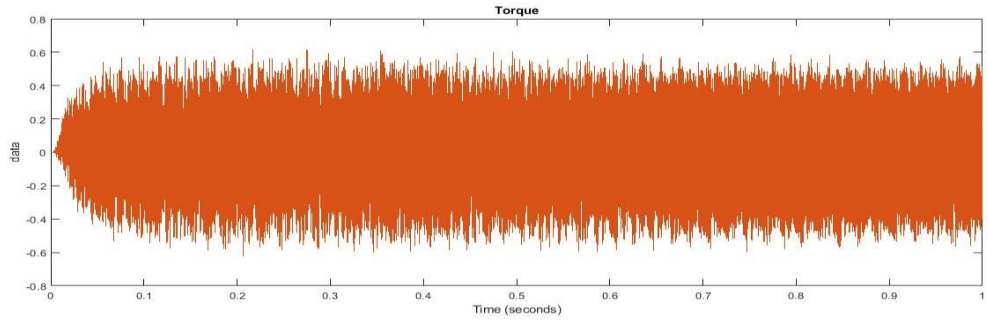

Figure23: Torque characteristics of single phase induction motor

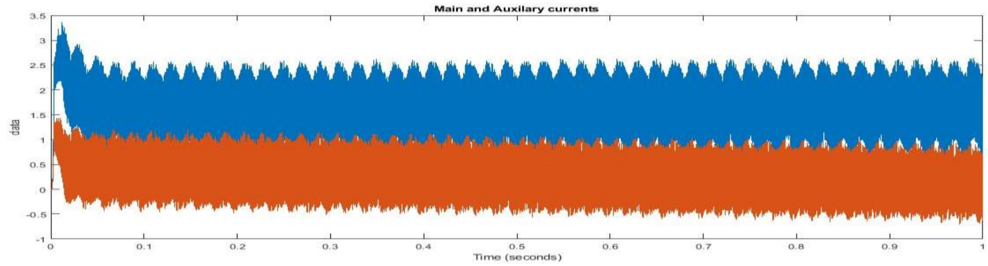

Figure 24: main and auxiliary currents characteristics of single phase induction motor

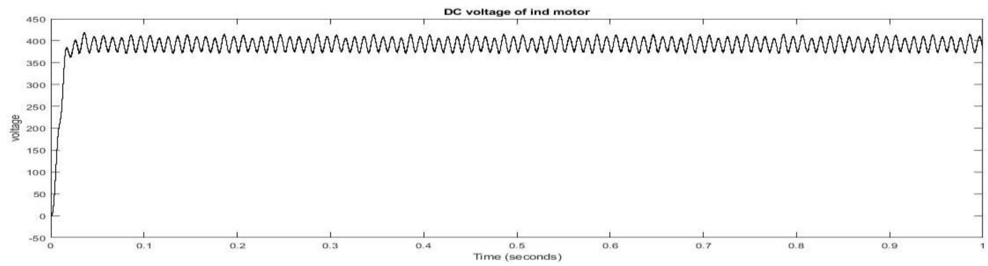

Figure 25: DC output voltage characteristics of single phase induction motor

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CONCLUSION

An interleaved boost converter with mppt algorithms rather than conventional boost converter is used for better performance .And here mainly two different techniques namely P&O and fuzzy logic control algorithms are implemented for the purpose of tracking the maximum power from the PV generator with the variation of the temperature and the irradiance. It is seen that the efficiency of the PV generator increase by using these method. While Comparing the P&O and fuzzy MPPT, the fuzzy logic controller based mppt gives lesser output voltage ripple and higher output voltage when used to give pulses to the switches for the interleaved boost converter. Thus interleaved boost converter is a better configuration for PV.

FUTURE SCOPE:

The proposed system interleaved boost converter along with Fuzzy MPPT techniques can be also be applied for the battery charging applications, fuel cell, and hybrid electric vehicle systems.These proposed system can also be examined for Grid connected loads.

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