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Maximum Power Point Tracking system for PV panel using SEPIC (DC-DC) converter

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***Abstract* - In this paper proposed work we design and implementation of Single Ended Primary Inductor Converter (SEPIC) converter and Voltage Source Inverter for an Induction Motor using Photovoltaic energy as a source. Commonly the more number of drives working for industrial and commercial applications are induction motor drives. To run such thoughtful of motor from the PV source, it is proposed to have a DC-DC converter and an inverter circuit as interface circuits. As the PV cell keep the nonlinear behavior, a DC-DC converter with Maximum Power Point Tracker (MPPT) controller is required to improve its utilization efficiency and for same the load to the photovoltaic modules. In this paper SEPIC converter (DC-DC converter) with Perturb and Observe MPPT algorithm is used for same the load and to boost the PV module output voltage. To convert the boosted DC output voltage from PV module into AC, a voltage source inverter with sinusoidal pulse width modulation is executed on it to achieve satisfactory voltage to drive single phase induction motor. The simulation work of these SEPIC converter and voltage source inverter fed induction motor circuits have been done using PSIM and Proteous software. The experimental work is accepted out with the SEPIC converter and voltage source inverter to drive the single phase induction motor. An ATmega16 pic microcontroller is used to generate pulses for controlling the SEPIC converter circuit.**

***Index Terms* - MPPT algorithm, PV cell,SEPIC converter, Voltage source inverter, Proteous software**

I. INTRODUCTION

The photovoltaic energy system has the advantages of absence of fuel cost, no environmental impacts, low maintenance and lack of noise and also it is a kind of renewable energy system. So it is becoming popular in the recent years, as a resource of energy. Modeling and simulation of PV array based on circuit model and mathematical equations are proposed [9]. As the photovoltaic (PV) cell exhibits the nonlinear behavior, while matching the load to the photovoltaic modules, DC-DC power converters are needed. There are several converter configurations suchas Buck, Boost, Buck-Boost, SEPIC, ĆUK, Fly-back, etc. Buck and Boost configurations can decrease and increase theoutput voltages respectively, while the others can do both functions. Buck, Boost, Buck Boost converters as interface circuits are proposed and analyzed in [6]. CUK and SEPIC converters are analyzed in [1,7].

When the solar insolation and temperature is varying, the PV module output power is also getting changed. But to obtain the maximum efficiency of PV module it must be operated at maximum power point. So it is necessary to operate the PV module at its maximum power point for all irradiance and temperature conditions. For this purpose Perturb and Observe MPPT algorithm is proposed [8].According to this MPPT output, the duty ratio of SEPIC converter is varied, that leads to changes in output voltage.

The function of an inverter is to change a dc input voltage to a symmetric AC output voltage of desired magnitude and frequency. To drive the three phase induction motor the output dc voltage of SEPIC converter is converted into AC by means of voltage source inverter.

In this paper PV source fed induction motor drive is proposed with SEPIC converter and voltage source inverter as interface circuits. Perturb and Observe (P&O) MPPT Algorithm is used to extract the maximum power point of PV module [8]. Sinusoidal pulse width modulation technique is employed for the control of voltage source inverter. The overall block diagram is shown in fig.1.

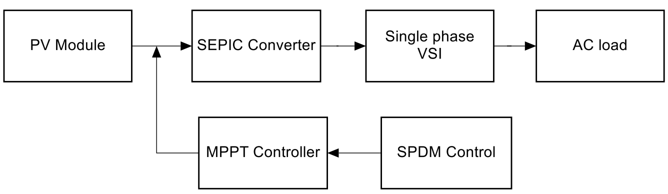

Fig.1 Overall block diagram

The hardware prototype of SEPIC converter and VSI is constructed to run the single phase induction motor. In the literature survey an analog controller is used to generate the gate pulses and to control the inverter output voltage [3]. In this thesis to generate the gate pulses for the switches, PICmicrocontroller is used in control circuit as given in [4, 5, 14 and15]. Along with PIC microcontroller, IRFZ44N driver circuit is needed to generate gate signal for SEPIC converter. The input DC voltage to the SEPIC converter is taken from the power supply unit. The two switches of VSI are gate controlled by using SG3524 PWM controller IC.

II. SEPIC CONVERTER WITH PV AND MPPT

PV system directly converts sunlight into electricity. The basic device of a PV system is the PV cell. Cells may be gathered to form modules or arrays. More sophisticated applications require DC-DC converters to process the electricity from the PV device. These converters may be used to either increase or decrease the PV system voltage at the load. The proposed SEPIC converter operates in boost mode.

PV Module Characteristics

Photovoltaic (PV) cell is a semiconductor device which directly converts the light energy into electrical energy. A PV system consists of a multiple component, including the photovoltaic modules, mechanical connection, electrical interconnections, and mounting for other components. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes [8, 10].The rate of generation of electric charge carriers depends on the flux of incident light and the capacity of absorption of the semiconductor. The absorption capacity are mainly depends on the semiconductor band gap, on the reflectance of the cell surface (that depends on the shape and treatment of the surface), on the electronic mobility, on the intrinsic concentration of carriers of the semiconductor, on the recombination rate of carriers, on the temperature, and on various factors [8].

Typically, photovoltaic (PV) cell generates a voltage around 0.5 to 0.8 volts depending upon semiconductor and the built-up technology. The numbers of PV cells are connected in series and parallel to get more amounts of voltage and current known as PV module and if many such modules are connected for any application to get desired amount of current and voltage then it is called as PV array [25].

I-V and P-V Characterization of PV Cell

PV cells can be modeled as a current source in parallel with a diode. When there is no light present to generate any current, the PV cell behaves like a diode. As the intensity of incident light increases, current is generated in the PV cell, as illustrated in Fig.2 given below.

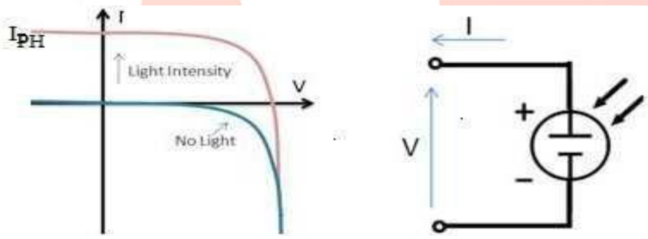

Fig.2 I-V Curve of PV Cell and Electrical Diagram

In an ideal cell total current supplied to the load I is equal to the difference between photocurrent generated by the semiconductor and diode current as shown in equation (2.1)[7].

$$I = I_{PH} - I_D = I_{PH} - I_0\left(e^{\frac{qv}{KT}} - 1\right) \qquad 2.1$$

The simplified equivalent circuit model of practical PV cell and I-V characteristics have been shown in Fig.3 and the related equation of the model are represented as equation (2.1). Where, A is the diode ideality factor (typically between 1 and 2), and RS and RSH represents the series and shunt resistances.

$$I = I_{PH} = I_{PH} - I_0\left(e^{\frac{q(v+IR_S)}{AKT}} - 1\right) - \frac{v + IR_s}{R_{sh}} \qquad 2.2$$

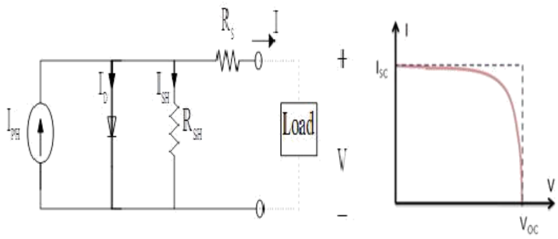

Fig.3 Simplified Equivalent Circuit Model of a Photovoltaic Cell and I-V Characteristics

III. MPPT Control Algorithm

Perturb and Observe algorithm (P&O)

There are various types of maximum power point tracking algorithms available. Among them, P&O algorithm is used here, since it has the advantages of high tracking efficiency, low cost, easy implementation etc. In this algorithm a slight perturbation is introduced in the system voltage. Due to this perturbation, the power of the module changes [8]. If the power increases due to the perturbation then the next perturbation is continued in the same direction. After the peak power is reached the power at the next instant decreases and hence after that the direction of perturbation reverses. When the steady state is reached the algorithm oscillates around the peak point [8]. In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. Fig.4 shows the flow chart of P&O algorithm.

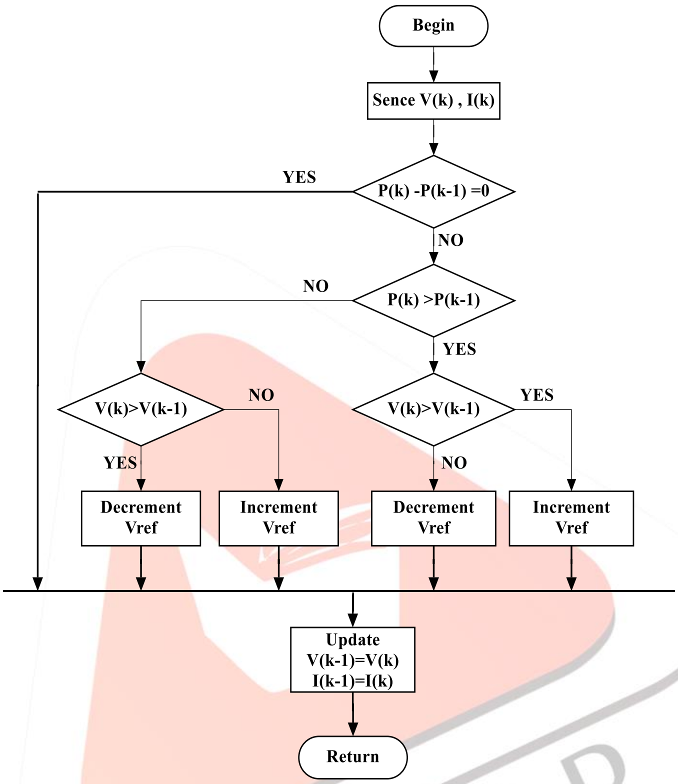

Fig.4 Flowchart of P & O MPPT algorithm

Incremental Conductance algorithm (IncCond)

This method is based on the fact that the slope of the power curve of the panel is zero at the MPP, positive to the left and negative to right. This method is based on the fact that the slope of the power curve of the panel is zero at the MPP, positive to the left and negative to right.

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V} 4.27$$

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} : \text{at the MPP}$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} : \text{left of the MPP}$$

$$\frac{\Delta I}{\Delta V} < -\frac{I}{V} : \text{right of the MPP}$$

The MPP can be tracked by comparing the instantaneous conductance G ci=I/V to the incremental conductance, ΔG=ΔI/ΔV as shown in the flowchart of fig.5

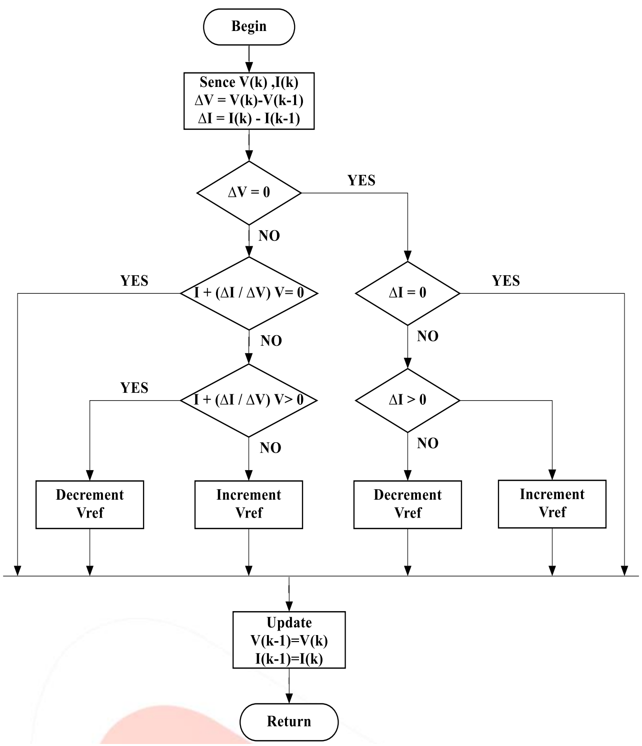

Fig.5 Flowchart of Incremental Conductance MPPT algorithm

IV. Modeling of SEPIC Converter

Nowadays, DC-DC converters are frequently used in many electronic gadgets like mobile, laptop, CD player of car etc. where available voltage source is constant and voltage requirement of the loads are different. In such case, DC-DC converter provides that required voltage without changing the power level. The power loss should be minimizing during power transfer from input to output of the converter. To implement the constant duty cycle MPPT algorithm a SEPIC (Single-Ended Primary Inductance Converter) is used. This DC/DC type of converter is an increasingly popular topology, particularly in battery powered applications, because the input voltage can be higher or lower than the output voltage. In this work, for the implementation of the maximum power point tracker the SEPIC, working in continuous conduction mode, is used as the power-processing unit. The PWM is controlled with a switching frequency of 3.5 kHz that actuates the MOSFET switch. The power flow is controlled by adjusting the on/o duty-cycle. Fig.6(a) & Fig.6(b) shows the schematic of the DC/DC converter implemented. It has one MOSFET, one diode, two inductances and tree capacitors.

For an ideal converter:

$$P_{OUT} = P_{IN}$$

This means

$$V_{IN} \times I_{IN} = V_{OUT} \times I_{out}$$

In case of lossy converter circuit so output power will be:

$$P_{OUT} = P_{IN} - P_{LOSSES}$$

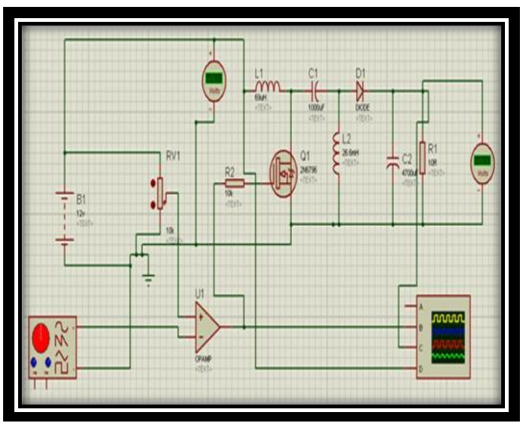

Fig.6(a) Proteus Model of SEPIC Converter

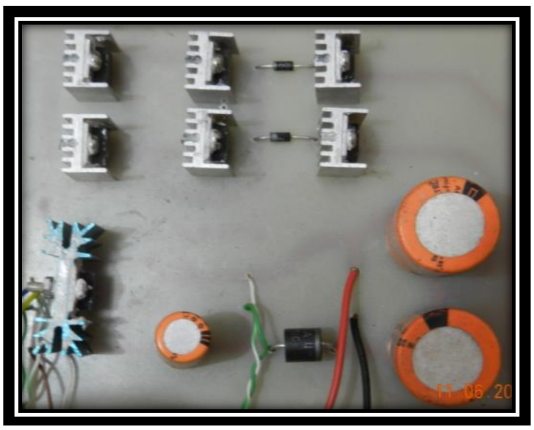

Fig.6(b) Hardware Model of SEPIC Converter

Table 1:- Specification of Components of SEPIC Converter

S. No.	Element	Specification
1	L_1	1.724mH
2	L_2	30.1mH
3	C_1	1000 F
4	C_2	4700µF
5	Diode	-
6	MOSFET	IRFZ44N

V. RESULTS AND DISCUSSIONS

In this proposed work our result analysis are divided into three sections

MOSFET Driver (also used as IGBT)

The real time proteous and hardware result of driver circuits has been shown in below. The below result shows the working limit of driver circuit. It has been observed that the proposed MOSFET driver works satisfactory up to 6 kHz as well as it is less expensive. This driver circuit doesn't give good response for the MOSFET and more than 7 KHz, this circuit not working for the Gate trigger for the MOSFET/IGBT.

Hardware Output:-

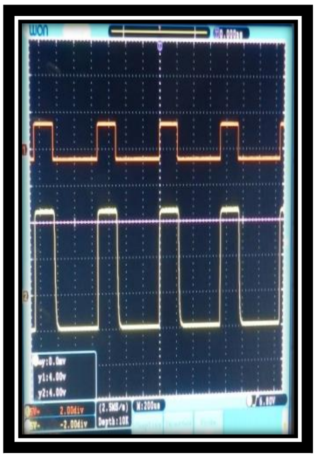

Fig.7(a) Driver Circuit Output at Duty Ratio is 30%

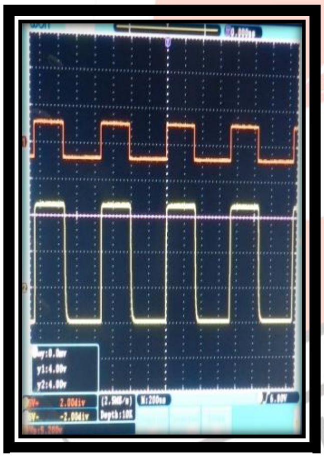

Fig.7(b) Driver Circuit Output at Duty Ratio is 40%

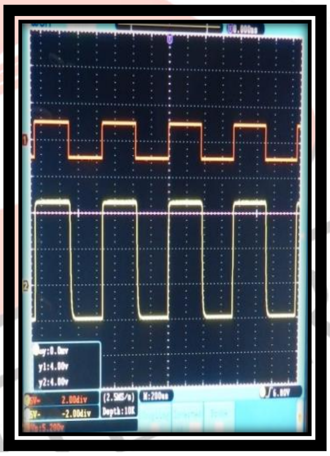

Fig.7(c) Driver Circuit Output at Duty Ratio is 50%

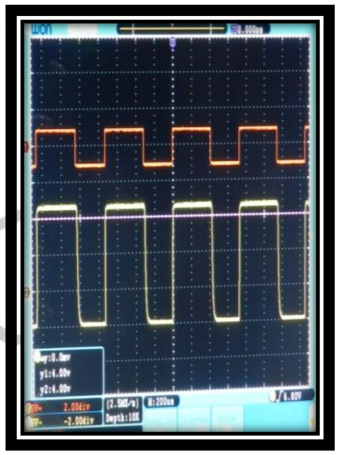

Fig.7(c) Driver Circuit Output at Duty Ratio is 60%

Software Output

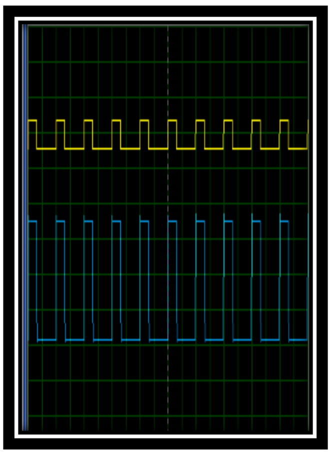

Fig.8(a) DSO Displaying Driver Circuit Output at Duty Ratio is 30%

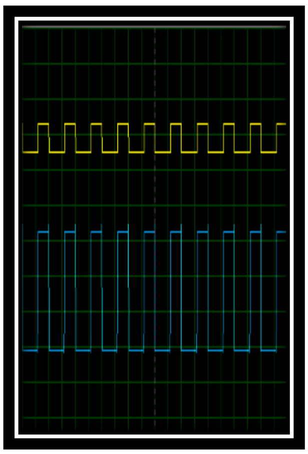

Fig.8(b) DSO Displaying Driver Circuit Output at Duty Ratio is 40%

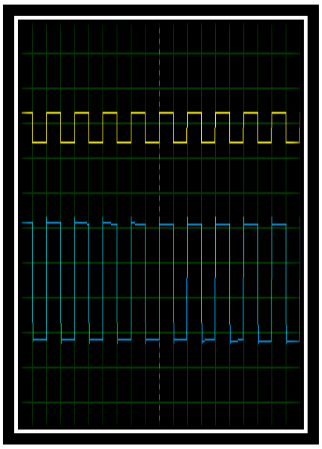

Fig.8(c) DSO Displaying Driver Circuit Output at Duty Ratio is 50%

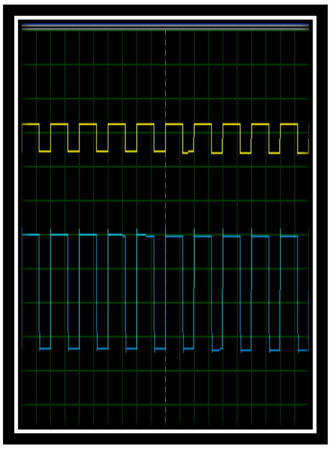

Fig.8(d) DSO Displaying Driver Circuit Output at Duty Ratio is 60%

SEPIC Converter (DC to DC converter)

SEPIC Converter with driver circuit

The proteous simulated and hardware output of SEPIC converter is verified by conversion ratio formula. The output of PV cell fed SEPIC converter for different duty ratio has been examined in Fig.9 and Fig.10 .

Software Output

Yellow: Output of microcontroller/input of the driver circuit.

Blue: Output of the driver circuit.

Pink: Output of SEPIC converter.

Green: Waveform of inductor L1.

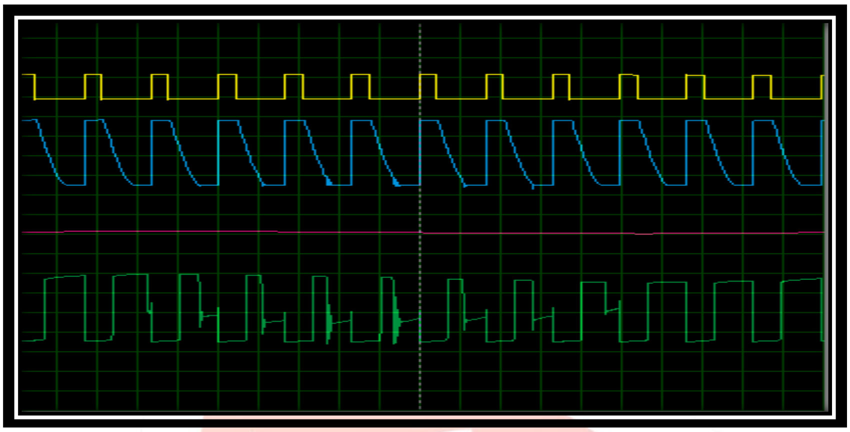

Fig.9 DOS Displaying an Output of SEPIC Converter

Hardware Output

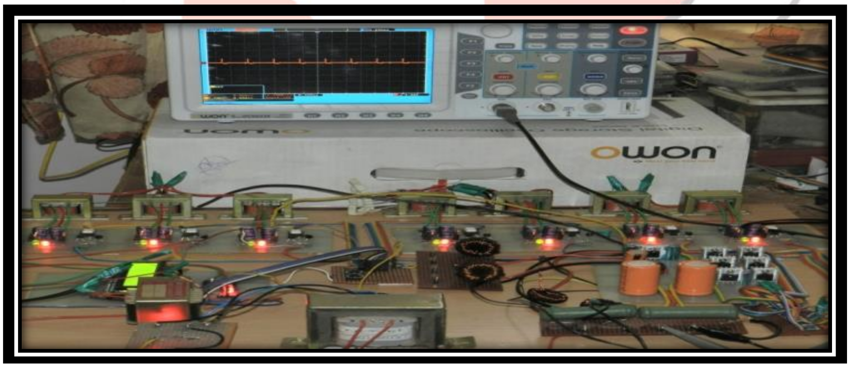

Fig.10 Hardware Output of SEPIC Converter

Tested Component of SEPIC Converter

Table 2 Specification of Components of SEPIC Converter

S .No.	Element	Specification
1	Input Voltage	12 volt
2	Load resistance	20 ohm
3	L1	1.724mH
4	L2	30.10mH
5	C0	1000uF
6	C1	4700uF
7	C2	4700uF

Analysis of Different Frequency SEPIC Converter Circuit:-

Table 3 Testing Frequency of SEPIC Converter Circuit

S. No.	Freq. (Hz)	Output voltage of SEPIC Converter (Volt)	C1 (Volt)	C2 (Volt)
1	2.63	1.916	.947	.972
2	10.45	5.30	2.6	2.3
3	20.19	8.27	4.07	4.14
4	30.24	10.39	5.16	5.19
5	37.3	12.11	6.04	6.02
6	55.5	15.48	7.81	7.77
7	80.8	18.42	9.26	9.16
8	100	19.15	9.74	9.56
9	152.5	18.70	9.38	9.29
10	200.6	17.01	8.54	8.46
11	231.9	16.78	8.53	8.34
12	251.9	15.65	7.86	7.78
13	302.1	14.71	7.32	7.32
14	457.1	13.05	6.54	6.51
15	707	11.68	5.84	5.83
16	1023	11.50	5.74	5.73
17	1204	11.65	5.81	5.70

VI. CONCLUSION

SEPIC converter and voltage source inverter were used as interface between PV module and the induction motor. P&O MPPT and Incremental Conductance Algorithmswas used to obtain the maximum power point operation of PV module. The simulation works of these circuits were carried out in the Proteous and PSIM software. The output voltage of inverter is increased and the current is reduced with the MPPT algorithm implementation. Experimental work has been done with the SEPIC converter and voltage source inverter to run the single phase induction motor using DC source. A PIC microcontroller was used to generate the pulses for driving the switch of the SEPIC converter. The boosted DC voltage of the SEPIC converter circuit output and inverted AC output waveforms were shown in the results.

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