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Wind Power Control Using MPPT and SEPIC Converter

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Abstract—A wind energy system is simulated by MATLAB/SIMULINK software. In which a SEPIC (DC/DC converter) converter is used to convert the varingDC voltage a constant output voltage by using its control mechanism.The amount of power output from a Wind Energy System (WES) depends upon the accuracy with which the peak power points are tracked by the maximum power point tracking (MPPT) controller of the WES control system irrespective of the type of generator used. Incremental conductance (InCond) method has been used as the algorithm in this MPPT block. The simulated system proposed uses a three-level, three phase, twelve pulse inverter for converting DC voltage generated by the SEPIC converter to AC voltage at desired frequency and voltage level. The usage of three-level inverter reduces Total Harmonic Distortion (THD) in output voltage. When large power generated from wind energy system then it will be stored in Battery, this stored energy will be used by load when system is shut-down or in unrealiable conditions. Lead-acid batteries are used due to their large availability in many sizes, low cost and well firm performance characteristics.
The main concentration here is to develop a system to make use of the available renewable resourcei.eWES effectively and increase the efficiency of system by implementing MPPT technique.

Keywords- *Wind Energy System (WES),SEPIC converter,Maximum Power Point Tracking (MPPT),Incremental Conductance Method (InCond), Three-level Inverter, Total Harmonic Distortion (THD) and Permanent Synchronous Generator (PMSG).*

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I. INTRODUCTION

The demand for electricity is increasing but the source is not enough for the demanded load hence this kind of generation of energy will match the demand this is the reason renewable energy sources [1] have become a popular substitute electrical energy source where power generation in conventional ways is not practical. In this paper Wind Energy is used which is renewable energy sources which is considered to be one good sources of energy.
Wind energy generation takes from watts to megawatts generation. India stands 5th place for Wind energy generation in world. Wind energy system which converts wind into electrical energy [2], where Wind turbineconverts rotational energy into mechanical energy as wind turbine is coupled to the shaft of generator as we know that generator converts the mechanical energy into electrical energy in this paper we are using Permanent Synchronous Generator due to its advantages like it eliminate gear box, reduces the losses, low maintenance cost and simple in control mechanism [3]. Output from the generator is AC in order to feed for SEPIC converter we are using universal bridge which convert AC into DC. A SEPIC converter is a DC-DC converter; SEPIC converter is used as intermediate converter to perform switching and regulated output. In many literatures it has proved that SEPIC converter is more efficient. A simple control technique which is also cost effective and has been projected to track maximum power point, is called maximum power point tracking technique. This is used under incessantly changing atmospheric condition like variable wind speed. Incremental conductance is a method which is frequently found in use because of its ease in implementation and effective tracking [4].
A software simulation model is developed in Matlab/Simulink. This kind of small scale stand-alone power generating systems can also be used in remote areas where conventional power generation is impractical.

II. OBJECTIVE

The main objective of the project is to implement a power system (i.e., Wind Energy System) in SIMULINK software and to apply various techniques to maximize the output power of the system.

1. PMSG is used as the generator to covert mechanical energy to electrical energy.
2. To trace the maximum power point tracking in WES irrespective of the changes in the environmental conditions.
3. To simulate a single ended primary inductance converter (SEPIC) so as to maintain a constant DC output voltage.
4. A 12-pulse inverter is to be designed which is used to reduce the total harmonics distortion in the system.
5. To show 12 pulse 3 level inverter is advantageous than 6 pulse 3 level inverter by FFT analysis.
6. To connect a battery which is used to store the excess power generated and in demand supplied to the load.

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III. METHODOLOGY

A. System Architecture

The block diagram of the proposed architecture is shown in Fig.1.

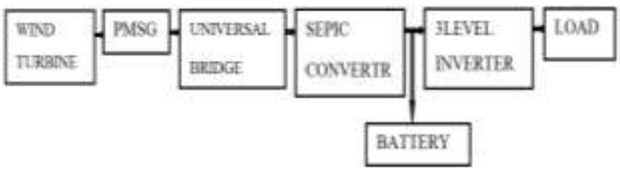

Fig. 1 Block diagram of proposed architecture

The input source is wind speed.The WES used is capable of generating 272 V. But the voltage may be less than 272 V sometimes if the wind speed is insufficient hence can fall below 272 V. Therefore, the output of the WES is fed through a SEPIC converter with a closed loop PI controller to keep the output of the WES voltage to a constant value of 500V DC.
The battery will be charged from this output.The output of the SEPIC is fed to a 3 level 3 phase 12 pulse inverter which converts it to 420V AC. For battery chargingvoltage should be kept constant so that smooth charging will safe battery life and its operations. In the absence of input power battery can supply the load for limited period.

B. Wind Energy System Modeling

Wind turbine converts kinetic energy of air i.e. wind power into mechanical power i.e. rotating motion of the turbine that can be used directly to run the generator. Power captured by wind turbine blade is concomitant of the blade shape, the pitch angle, speed of rotation, radius of the rotor. The equation for the power generated is shown below**.**

$$\mathbf{P_M = \frac{1}{2}\pi\rho C_P(\lambda,\beta)R^2V^3} \text{Equation 2}$$

Where

P_M– Power captured by wind turbine
ρ– Air density
β– Pitch angle (in degrees)
R– Blade radius (in meters)
V– Wind speed (in m/s***)***

C. DC-DC Converter

The most efficient manner of regulating voltage through a circuit is by a dc-dc converter.
Buck-boost converters are cheaper because they have one inductor and a capacitor in their design. On the other hand, these converters are put up with a high amount of input current ripple which can cause harmonics. This often makes the buck-boost expensive or inefficient. The output voltage of buck-boost converters is inverted which is again a disadvantage. A Cuk converter uses an extra capacitor and an inductor hence solving both of these problems, both Cuk and buck-boost converter cause large amounts of electrical stress on the components, this can result in device failure or overheating.SEPIC converters solve both of these problems [5].
The duty cycle of SEPIC converter is varied by using MPPT algorithm. A SEPIC converter is used on the load side and a solar panel is used to power this converter.

D.Maximum Power Point Tracking Technique

The efficiency of a WES is very low in order to increase it, methods such as Maximum Power Point Tracking is used. There are numerous MPPT algorithms which have been published. The aspects from which they differ are complexity, sensors required, cost or efficiency [6] [7].
MPPT technique is used to obtain the maximum possible power from a varying source in photovoltaic systems. As the wind speed is non-linear thereby making it difficult to be used to power a certain load. The change in the MPP voltage in incremental conductance algorithm can be determined with the slope of the curve power vs. voltage (current) of the PV module and by comparing the increment of the power vs. the increment of the voltage (current) between two consecutives samples.

E. Multilevel Inverter

An inverter is used to convert DC to AC power at a desired ac voltage. The better method for powerful output can be done by pulse width modulation control (PWM). By implementing this method, a constant dc input voltage is disposed into the inverter. Also an unflappable ac output voltage is accessed by regulating the on and off duration of the inverter units. PWM techniques are represented by fixed amplitude [8] .
Inverter produces the harmonics and effects power factor the system. Therefore, reduction of the total harmonics is very important especially for high power applications. The main objective of the PWM is to control the inverter output voltage and to reduce the harmonic content in the output voltage.

IV. SIMULATION IN MATLAB

Wind System delivers a maximum of 20kW at 11.7m/s wind speed.The SEPIC converter increases the voltage from wind energy system voltage (272 V DC at maximum power) to 500V DC. Switching duty cycle is optimized by the MPPT controller that uses the ―Incremental Conductance technique.
A 5kHz 3-level 3-phase 12 pulse Inverter(VSC), inverts the 500 V DC to 420 V AC and keeps it in unity power factor.

The simulation model of PV system is shown in Fig. 2

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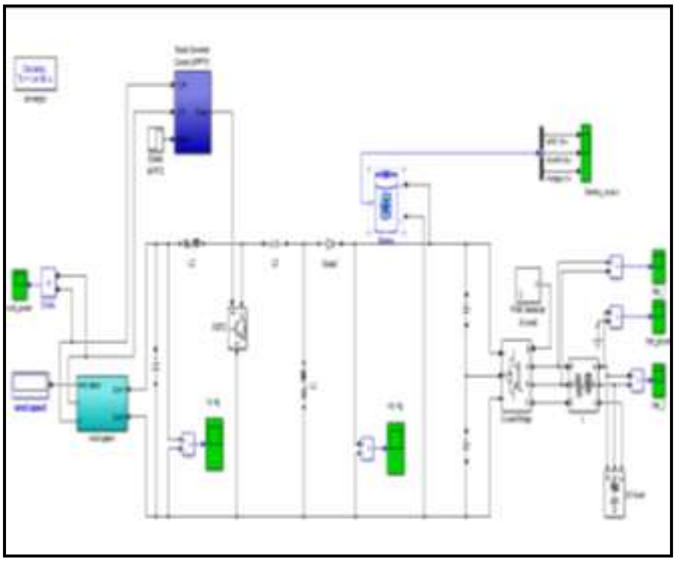

Fig. 2 Simulink model of PV array

The above Simulink model is made to run for 1 second and observation of the following sequence of events was made through scopes available. Various wind speed changes are applied in order to illustrate the good performance of the MPPT controller. Fig. 3 shows the input to wind turbine, Fig. 4 output of WES which is fluctuating which is feed to SEPIC converter.

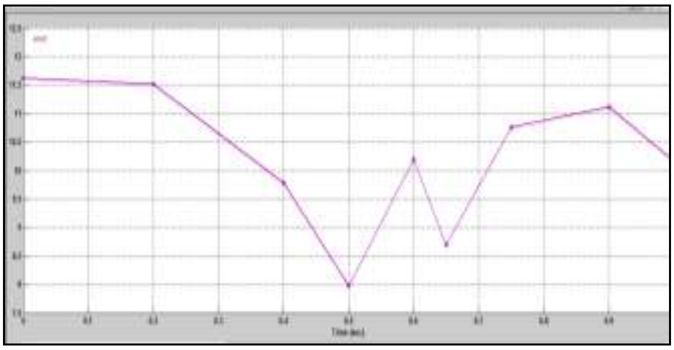

Fig.3Input to the wind system (wind speed)

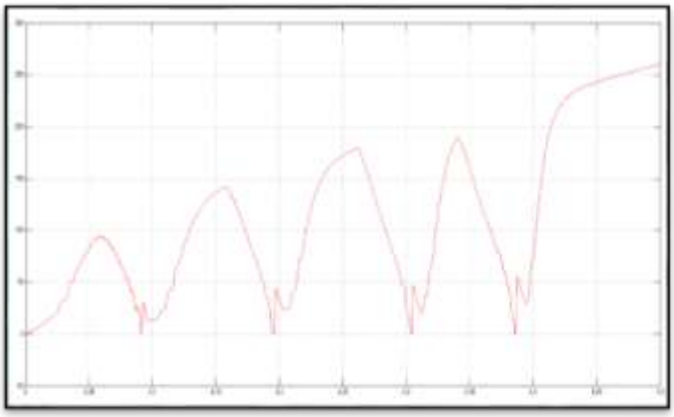

Fig. 4 Wind system output with fluctuation

Output voltage after maximum power point tracking are manifested in the Fig.5.The fluctuations in the output are eliminated and the voltage is maintained constant at 500V DC.

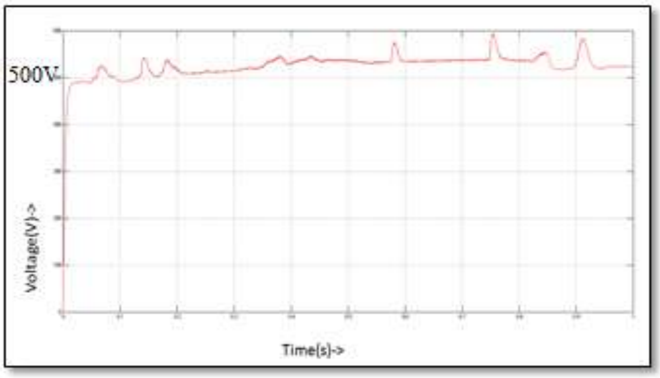

Fig.5 Output Voltage of SEPIC Converter

A 5 kHz 3-level 3-phase 12 pulse Inverter can be designed by using a block in Matlab/Simulink library.
The output voltage waveform of the Inverter is shown in Fig.6 and Fig.7

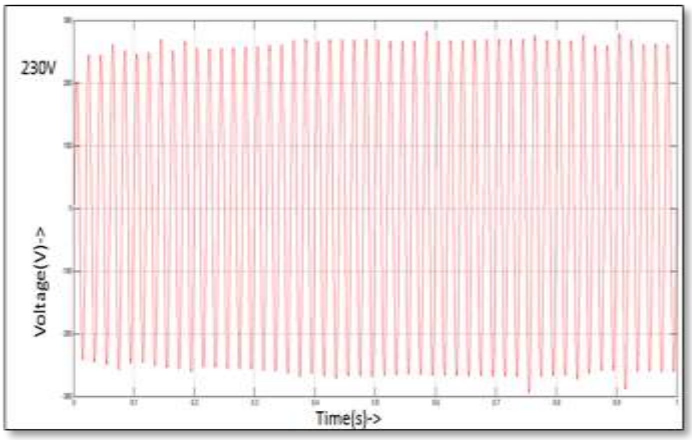

Fig.6 Output Line Voltage of three phase Inverter

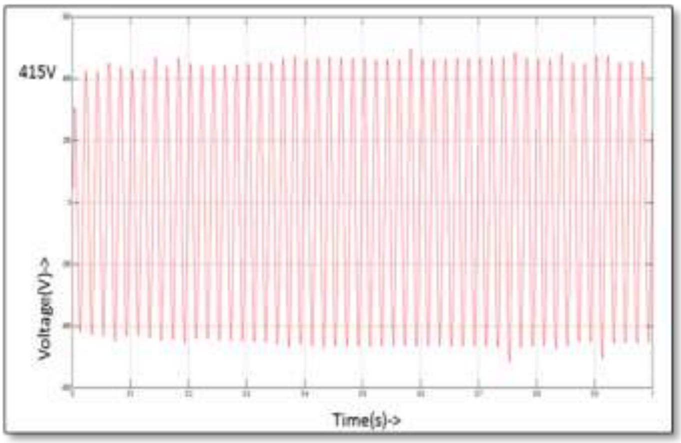

Fig.7 Output Phase to ground Voltage of three phase Inverter

The power quality improvement was done in simulation by using multilevel Inverter which reduces the harmonics. FFT (Fast Fourier Transform) analysis was carried out for both 6

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pulse (Fig. 8) pulse and 12 pulse (Fig. 9) 3phase Inverter and the value of 3rd and 5th harmonics were observed. With increase of pulse in the inverter (from 6 to 12), the total harmonic distortion (THD) has found to be reduced (nearly by half the value) andefficiency of the system has increased.

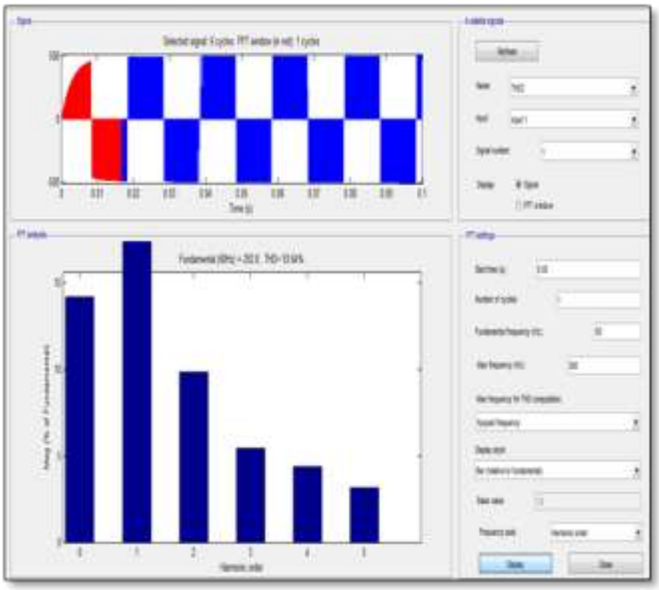

Fig.8 FFT Analysis(6 Pulse)

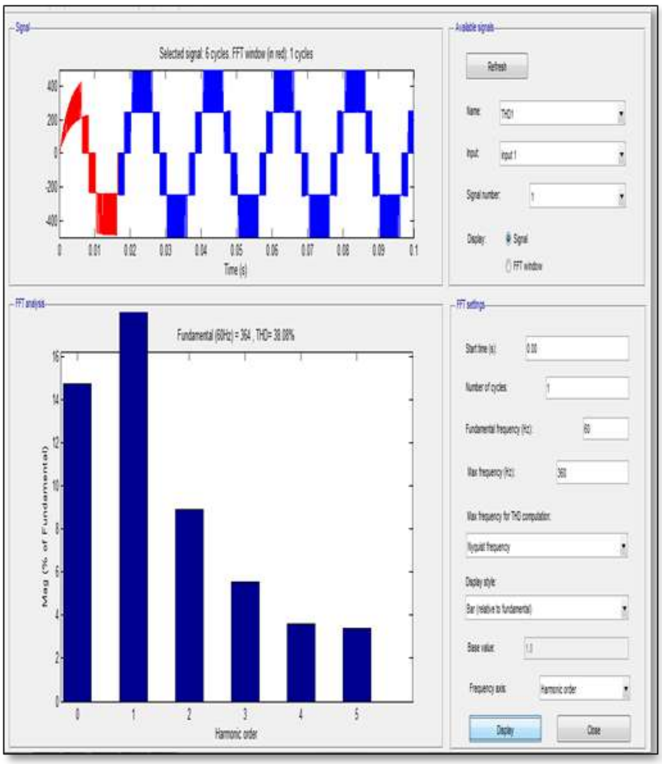

Fig.9 FFT Analysis(12 Pulse)

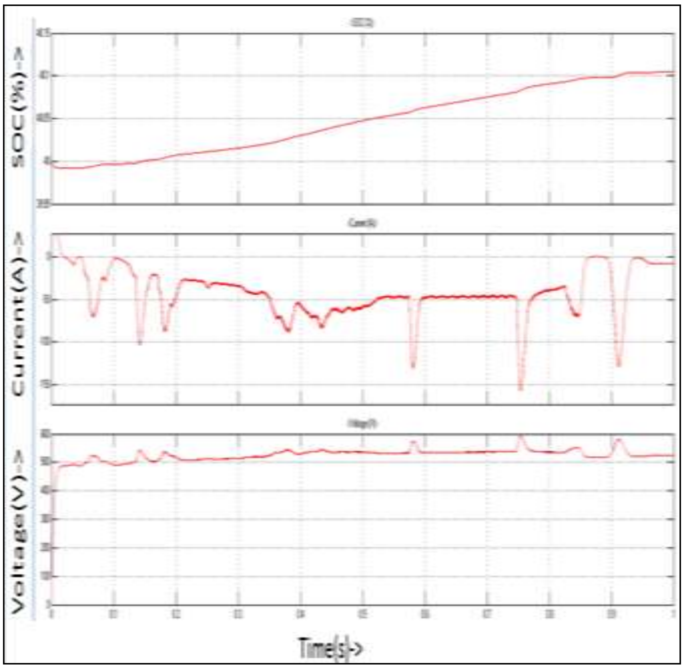

Fig .10 Output of the battery a) SOC(%) b)Current (A) c)Voltage(V) vs Time(s)

We can observe that during charging state of charge (SOC) of the battery is gradually increasing and also during charging current is negative. As state of charge of battery is increased battery voltage exceeded its nominal voltage (Fig.10)

Wind Speed (m/s)	**Wind system voltage(volts)**	**SEPIC Output voltage (volts)**	**Output Power (kw)**	**Output voltage (volts)**
12	250	500	10	415
11.5	240	500	10	415
11	220	500	10	415
10.5	200	500	10	415
10	181	500	10	415
9.5	178	500	10	415
9	172	500	10	415
8.5	170	500	10	415
8	164	500	10	415
7.5	160	500	10	415

Table 1 Analyses of Voltage and Power at different Wind Speed.

The above mentioned table presents that at different speed what will be voltage of WES, SEPIC converter voltage, total power of system generated and the total output of a system.

V. CONCLUSION

In order to convert wind energy efficiently the maximum power was achieved by maximum power point tracking system. The wind energy system output characteristics are simulated under different speed levels.

SEPIC converter is used to maintain constant voltage of 500V at different irradiance levels. The output of the inverter is 415V at 50Hz AC. The harmonic distortions present in the load current and voltage waveforms were observed and calculated through FFT analysis tool in Matlab/Simulink. The system generates total power of 10kW. The functionality of the proposed power converter has been demonstrated by simulation and the obtained results are satisfactory.

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