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Design of 100watt Wind Power System using Brushless DC Generator

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***Abstract-*. In the recent years lot of development has been done to extract energy from solar and wind, many researchers have presented small energy plants for home applications. But since the solar energy is available only during the day and is continuously varying, it is necessary to store the energy. Therefore it can be replaced by a small renewable energy system. In this paper, we have demonstrated the system for conversion of renewable energy wind into useful electrical energy. The bi-directional converter is an important part of the circuit. Bi-directional converter can supply power to load as well as feedback energy in to the grid. A small 100watt system is designed, simulated and experimental setup is under construction.**
Keywords-Tip speed ratio, Bidirectional converter, BLDC generator, wind turbine.

I. INTRODUCTION

The increasing growth in technology has led to increase in need of energy resources to suffice them. A lot of development has been done to use the available renewable energy i.e. solar energy for satisfying the energy applications. But the disadvantage of solar energy is that it can be available only during sun hours and is continuously fluctuating throughout, hence there is a need to store this energy.

Hence an alternative energy system should be designed to overcome the battery storage problem. Wind energy is dynamic in nature. Wind is a cubic energy resource. As the wind speed increases, the power available increases three times. Wind energy is the least expensive source of new electric power that is also compatible with environment preservation programs. Many countries have promoted wind power technology. Wind energy does not produce any toxic emissions and is thus a clean source of power. Most of all, its free of cost and many developments can be made to scale its applications.

The speed control during power generating mode and stopping the turbine when required is an important design issue. The converter operates in both the directions , it generates power supplied to grid as well as feeds energy back to the load. Hence the selection of a BLDC generator and bidirectional converter becomes justified.

The output from a BLDC generator is given through bi-directional converter connected to a three phase power grid. From there it can be used for various purposes.

II. DESIGN OF SYSTEM

The block diagram of the system is as shown in Figure. It shows the basic building blocks of the system.

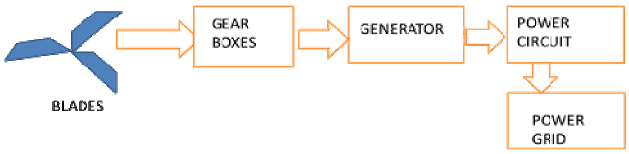

Fig.1 Block diagram of wind power system

A. Wind Blades and Gear Boxes:

A gearbox is typically used in a wind turbine to increase the rotational speed from a low-speed rotor to a high speed electrical generator, in this case a brushless DC generator.

The tip-speed ratio, or TSR for wind turbines is the ratio between the tangential speed of the tip of a blade and the actual velocity of the wind, 'v' in meter/seconds. The tip-speed ratio is related to efficiency, with the optimum varying with blade design. Higher tip speeds result in higher noise levels and require stronger blades due to large centrifugal forces.

$$TSR = \frac{\textit{Tip speed of of Blade}}{\textit{Wind speed}}$$

The tip speed of the blade can be calculated as 'w' times 'R', where 'w' is the rotor rotational speed in radians/second, and 'R' is the rotor radius in meters. Therefore, it can also be expressed as:

$$TSR = \frac{wR}{v}$$

A wind turbine installation consists of the necessary systems needed to capture the wind's energy, direct the turbine towards the direction of the wind, convert mechanical rotation into electrical power, to start, stop, and control the turbine.

Considering a 100watt design, for a wind speed of 4meter/seconds the blade dimensions should be 0.99m or 2.9feet in height.

B. BLDC Generator:

BLDC generator generates the three phase AC output. Specifications are 100w, 24Vdc, 300rpm.

- he voltage, current ratings and torque required at rated speed (300 rpm) were observed and studied. Thus we observed the waveforms of the BLDC generator where line voltages are shifted by 60 degrees.
- he regulation is observed to be 35%.
- hen load is connected at output the voltage drops and slope decreases with load.

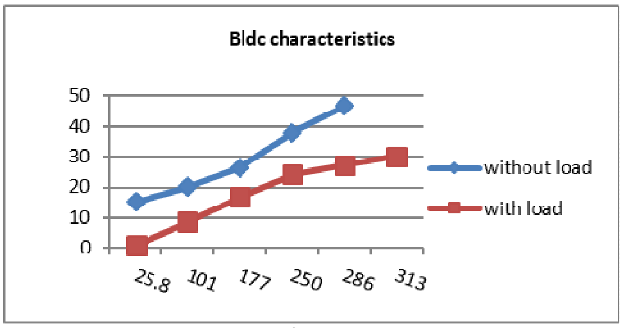

Fig.2. Characteristics of BLDC generator with and without load

Rather than controlling the turbine rotation speed to obtain a fixed frequency synchronized with the grid from a synchronous generator, the rotor and turbine can be run at a variable speed corresponding to the prevailing wind conditions. This will produce a varying frequency output from the generator synchronized with the drive shaft rotation speed. This output can then be rectified in the generator side of an AC-DC converter and the converted back to AC through an inverter in grid side of the converter which is synchronized with the grid frequency as shown in block diagram.

fig.3 Brushless DC generator

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C. Bidirectional Converter

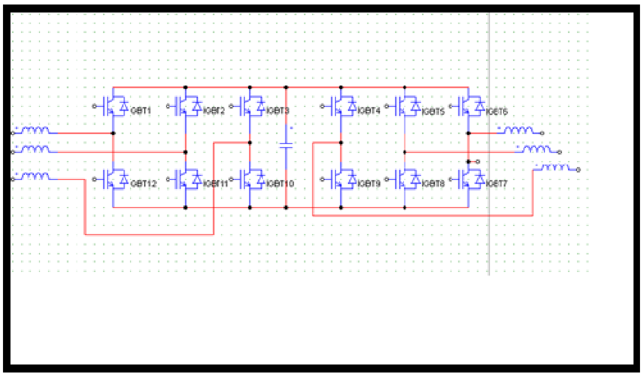

Fig.4 Bidirectional converter

We are using a bidirectional converter here as wind generation system has two modes:

<u>MODE 1]</u>

Initially the generator acts as motor when the wind speed is very low and the power is drawn from Utility Power Supply. The bridge shown in the diagram has two converters. The converter 1 works as inverter and converter 2 works as rectifier.

<u>MODE 2]</u>

When the wind speed is very high or increases ; the anemometer senses the wind velocity and transfers the system to generating mode. In the bridge shown the converter 1 works as rectifier and converter 2 works as inverter; power is fed back to Utility Power Supply.

The generator block will come into picture when the controller detects that the wind velocity is high. When the wind velocity is high, converter 1 will work as a boost rectifier and converter 2 will be inverter; as initially the generator acts as motor when the wind speed is very low and the power is drawn from Utility Power Supply.

The motoring block will come into picture when the controller detects that the wind velocity is low. When the wind velocity is low, converter 1 will work as an inverter and converter 2 will be boost rectifier and hence the system to generating mode where power is fed back to Utility Power Supply.

- IGBT selection

RMS current of IGBT=16.94A and peak current Ipeak=29.34A.
Hence we select IGBT 25N120 because it is readily available.
The following features:

- Calculations for three phase inverter
  - RMS Line voltage Vrms=0.707*Vin
  - We have Vrms line voltage(3 phase) =415V
  - Hence Vin=Vdc=586.98V

Therefore Vdc bus required for the inverter is 586.98V.

- Filter calculation:

With 5th harmonic at 250hertz and 7th harmonic at 350hertz, the following calculations
For the LC filter
Capacitive reactance

Xc=1/(wc) [Xc=10ohm]

Hence

C=63.6uFarad at 250 hertz
C=45.4uFarad at 350 hertz

But practically we do not get a smooth sine wave . Hence capacitors with

C1=636uFarad and C2=454uFarad are

connected in parallel at the load.
We use standard capacitors 650uF and 450uF.
A snubber circuit protection against the overcurrent is required for the IGBT switches

- Snubber design:

  The characteristic impedance Z is calculated as
  If L is known Z=2*pi*fc*L
  If C i s known $Z=\frac{1}{(2*pi*fc*C)}$
  Rsnubber=Z
  $Csnubber=\frac{1}{(2*pi*fc*R)}$
  For fc=250hertz
  C=0.1uFarad and r=6.3Kohm

- Heat sink calculations

  conduction losses:
  P=V*I*(Duty cycle)
  =2*0.16*0.33
  =0.1056 watts
  switching losses:
  P=0.5{Vsupply*If*[(tr+tf)/2]*f}
  =0.5{800*4*(1.07*10ˆ-7)*4.188}
  =0.7169 watts
  total loss=C.L.+S.L.
  =0.1056+0.7169
  =0.8225 watts
  $\phi\ ja = \frac{Tj - Tambient(max)}{power\ dissipation}$
  ϕ sa= ϕ ja-(ϕ cs + ϕ jc)
  $\phi\ ja=\frac{100-25}{0.8225}$
  =91.185
  ϕ Sa=91.185-(0.06+0.62)
  =90.505°C/Watts

Hence heat sinks corresponding to the above value should be

PARAMETER	VALUE
Collector emitter voltage Vces	1200V
Collector current Ic at 25 ̊	50A
Maximum power dissipation	200W

selected for the IGBT switches.

D. Controller Block

The whole mechanism is controlled by a microcontroller based control circuit. The inputs given to the controller are-

Wind speed:
If the wind speed is higher than given threshold, it gives signal to the pulse generator and the bridge works as rectifier generating DC. If wind speed is lower than threshold value, it enters into the motoring mode to provide the initial torque for the blades to rotate.

Wind direction:
The motor rotates in direction provided to controller, to attain maximum power in aligned position.

Output sensor:
The output DC is sensed and given to microcontroller. This provides a signal whether if, output is generated at that instant or else initial torque is to be given.

Position of blades:
Signal carrying information about whether the blades are moving, steady or stationary condition is given input to microcontroller**.**

III. DATA ANALYSIS

We know that the energy contained in the wind can be converted into useful energy through wind mills.

The power 'P' contained in the blowing wind depends on its velocity 'v' in m/sec and density of air 'p'

P= (1/2)* p* v^3*A watt

Where A=Rotor area.

We had visited **CRL , Ooty** and observed that the kinetic energy of wind is sufficient; especially from June to October, hence it will prove beneficial to install a wind power system there.

According to the data obtained through field study at **CRL,Ooty** the graph is plotted as:

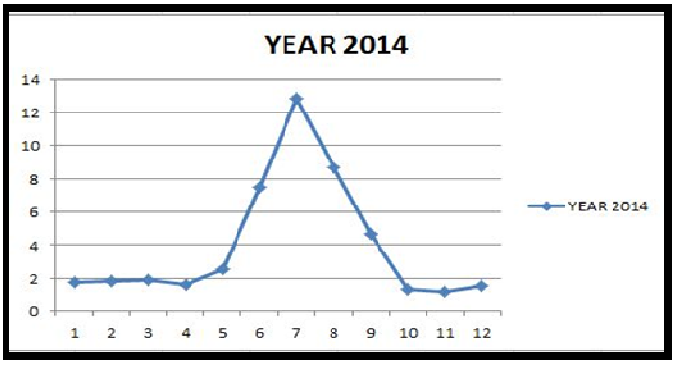

Fig.5 Yearly average of wind speed at CRL,ooty. Month vs Wind speed

The average wind velocity calculated is 4 meter/seconds. Thus we have determined that the power generated at Ooty will be approx. 1.16KW.

III. SIMULATION AND RESULTS

The bidirectional converter consists of a boost rectifier and 3phase inverter. The following figure displays the working of a 3 phase inverter and its output. It operates in the 120degree mode of conduction i.e. only two switches are on at a time. A filter is connected at the output to obtain a smooth sine wave.

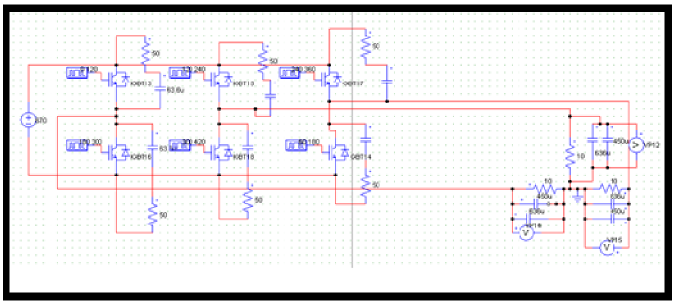

Fig.6 Three phase inverter

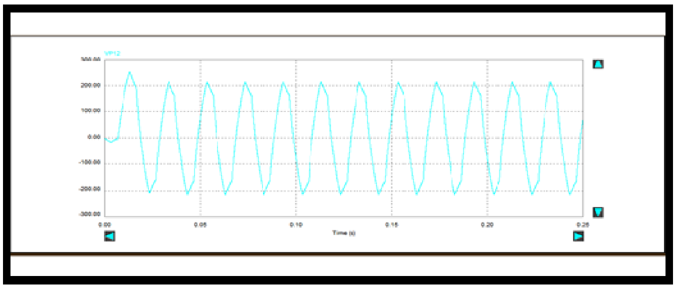

Fig.7 Output of three phase inverter

The controller circuit uses a PIC16F676 microcontroller for generating pulses to be given to the gate of the IGBT switch. The pulses are generated according to the operating conditions of the circuit. Thus the figure shows the circuit for the controller and its output.

For the inverter working in 120degree mode the gate pulses generated are shifted by 60degree.Hence for a given time slot only 2 switches remain on. Considering 33% duty cycle the ON time is 33.33msecs.Therefore a 17msec delay is required for a 60deg phase shift.

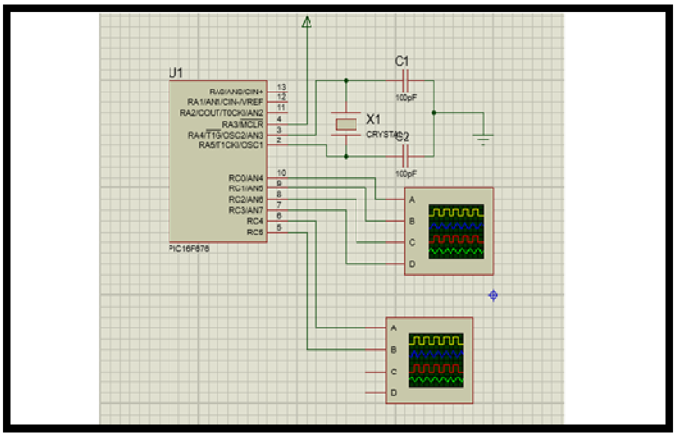

Fig.8 Controller circuit for 3 phase inverter

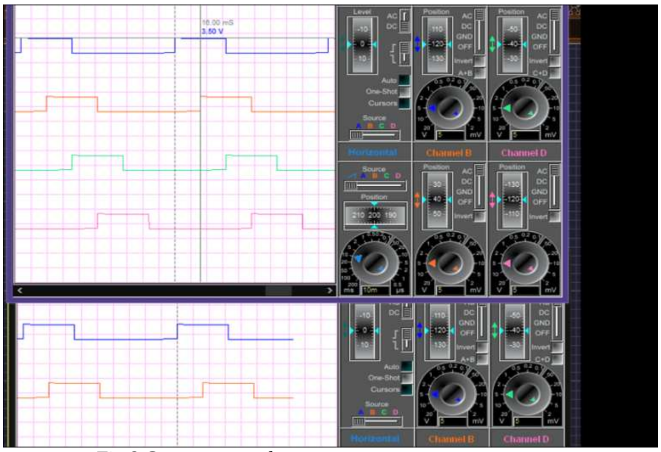

Fig.9 Output gate pulses

IV. FUTURE PLAN

- The design for boost rectifier and its control circuit will be completed after troubleshooting of the inverter.
- After which the mechanical system would be developed.
- Hence, the installation of the prototype at VIIT,Pune.

V. APPLICATIONS

- tand alone system for Home applications.
- ystems for Community Centres, Schools and Health care centres..
- ndustrial applications.
- rid- connected power systems.
- he system is designed for 100 Watt power application. It is further scalable
- his will reduce the strain on the utility power supply as the grid can be used to provide supply to required load.

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VI.CONCLUSION

- Hence the simulations are obtained according to the theoretical calculations.
- A 100watt power system design can be set up with these results.

VII. ACKNOWLEDGMENT

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