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Control of Small Wind Turbine in the High Wind Speed Region

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Abstract: This paper proposes a control strategy for small wind turbines operating in the high wind speed region. This control also used to store the excess energy obtained from the generator due to the high wind speed and uses it in the future when there is a scarcity of required wind speed. The simulation results and the experimental results of the proposed method is explained below.

Kaywords: The components needed for the controlling are permanent magnet synchronous generator, rectifier, boost converter, H-bridge inverter.

I. Introduction

Why wind energy is needed? Wind energy is the one of the renewable energy available in mass volume. Compared to the solar energy which can be obtained only during the day, wind energy is available at any time and at anywhere. The conversion of wind energy into electrical energy is easier than converting the solar energy in to the electrical energy. Now a days wind turbines are used in many areas for the production of electrical energy. At first there were only the wind turbines which rotates only on the fixed wind speed, but now a days variable speed wind turbines are used which rotates on variable speed conditions. This control method is provided for the variable speed wind turbines.

Problems faced in small wind turbines: The problems faced by the small wind turbines is their capability to withstand the high wind. When the wind speed is higher then the expected speed. The braking of the turbine is not possible. There were several control methods which contributed for controlling the small wind turbine, but most methods faced the problem of being cost effective. At last, the new control strategy is developed which is cost effective. This control method consists of permanent magnet synchronous generator (PMSG) which is connected to the wind turbine and the other side is connected to the rectifier in order to convert ac to dc. The output from the rectifier is taken to the boost coverter where it is boosted according to the required output. The dc output from the boost converter is given to the h-bridge inverter which converts the dc to ac and injects the current in the grid. Line side inverter maintains the
dc-link voltage constant and the power factor of line side can be adjusted. Input current reference of boost chopper is decided for the maximum power point tracking of the turbine without any information of wind speed nor generator rpm. As the proposed control algorithm does not require any speed sensor for wind speed or generator rpm, construction and installation are simple, cheap, and reliable. [1]

II. System Description

The block for the controlling of small wind turbine under high wind speed conditions is given below.

A. small wind turbine:

The wind turbine is used to harness energy or power from the wind and pass it to the generator for the conversion of electrical energy. The power developed using the turbine is as follows

$$P_W = \frac{1}{2}\rho A a C_P V^3$$

Where

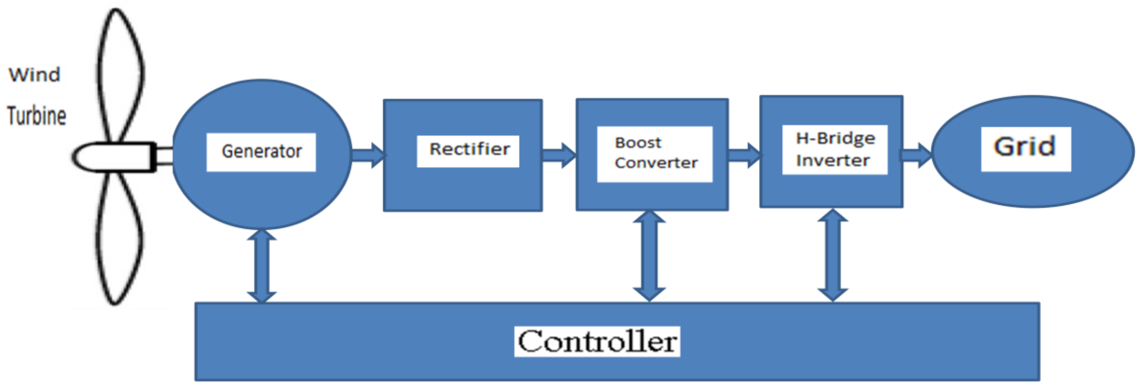
P_W = wind power $[W]$

ρ : air density $[kg / m_3]$

A : swept area $[m_2$

C_P : power coefficient of wind turbine

v : wind speed $[m/ s]$



B. Permanent magnet synchronous generator:

The permanent magnet synchronous generator is used to convert the wind energy in to the electrical energy. This electrical energy obtained is the ac and it is sent to the rectifier for conversion of ac to dc, or it is also sent to the controller under high speed conditions. The power obtained from the PMSG is one of the needs for controlling the small wind turbine. Permanent magnet synchronous generator is the highly suitable energy conversion for the small scale. The output voltage from the PMSG is needed to be rectified because of its variable frequency and variable voltage nature.

C. Power converter topologies:

It consists of rectifier, boost converter, H-bridge inverter. The rectifier is to rectify the output voltage from the PMSG and send it to the boost converter. As mentioned above under high wind speed conditions, the output from the PMSG is compared with the demanded current. The duty cycle is already produced for the PMSG which has some constant voltage in the controller. based on the increase or decrease in the comparison, the energy is stored or used away. The boost converter boost the voltage when the there is the decrease in the wind energy to the required voltage which is constant. The H-bridge inverter is used to inject the right amount of voltage that the system can inject in to the grid. All the power converter topologies are controlled using the microcontroller.

D. Maximum Power Point Tracking Controller:

The method of maximum power point tracking characteristic of the wind turbine is explained where the power versus speed characteristic is determined. It is evident that for a certain wind speed, the power output from the wind turbine increases as the turbine is allowed to increase the rotational speed. This increase continues up to a certain speed, beyond which the output starts to decrease. There is an optimum rotational speed which provides the maximum production of the available power in the wind stream. The curve joining these points is the maximum power locus and is the objective of the paper to operate the system along it.[2]
This controller has the output voltage which helps in operating the system when the voltage obtained is greater then the minimum demanded voltage, thus the MPPT lock starts producing an additional reference voltage that is used to track the maximum power point of the system. When the current obtained is larger than the limited current due to the high wind speed, the voltage reference is held constant.

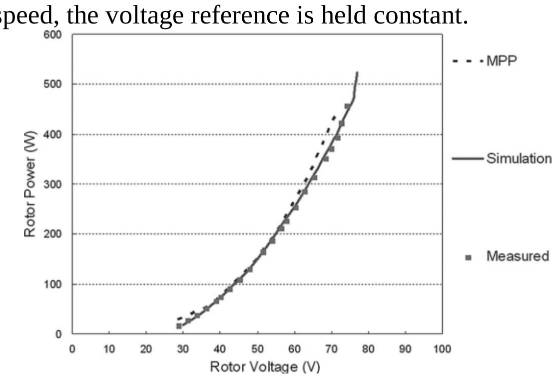


Fig:2 The increase in the output power for different wind conditions.

The graph explains how the MPPT controller works on the starting condition. It detects the voltage and the current produced from the wind using the PMSG and calculates the power output using the voltage and current. The power produced is compared with the previous output power obtained for different wind speed. If the power increases, the reference power is adjusted to obtain the constant power output. If the power decreases, the output power adjusted to obtain the demanded power. If there is equality between the previous power and the obtained one, the there is no changes in the power output.

III. Simulation results

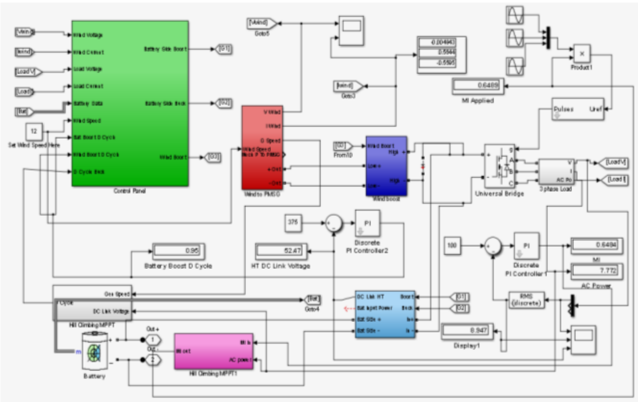
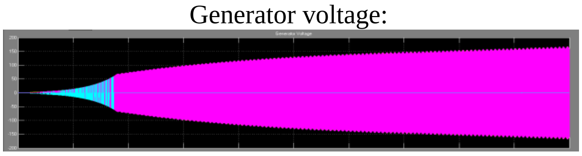


Fig 3. Simulation diagram for controlling small wind turbine using PI controller.

The simulation diagram has the control panel from which the inputs for every components are given through this control panel. The wind speed is taken as average high speed as 12m/s for which the generator voltage and the generator current is obtained is given in the fig 4. The PMSG is connected along with the rectifier inside the lock diagram. The simulation is done for the 3-phase grid connected design. Here two control loops are used, one is for controlling the power output from the generator and other is to control the injection of the power in the grid. The dc link voltage is produced by comparing the previous output to the present output obtained.

The hill climbing MPPT is used which controlling method is explained above in the section D. The excess energy which is unnecessary is stored in the battery for the future use when the wind energy is not available. This is the control method proposed for the smooth working of the small wind turbine under high wind speed conditions.

Generator voltage:



Generator current:

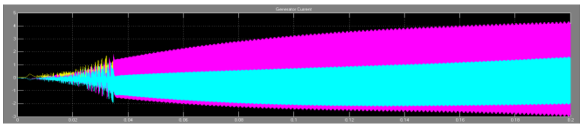
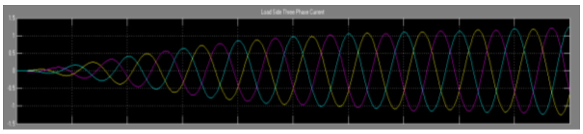


Fig 4. Voltage and current output from the generator on both d and q axis.

OUTPUTS:

Load side current:



DC link voltage:

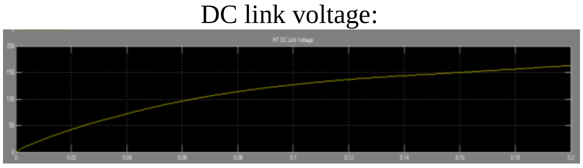
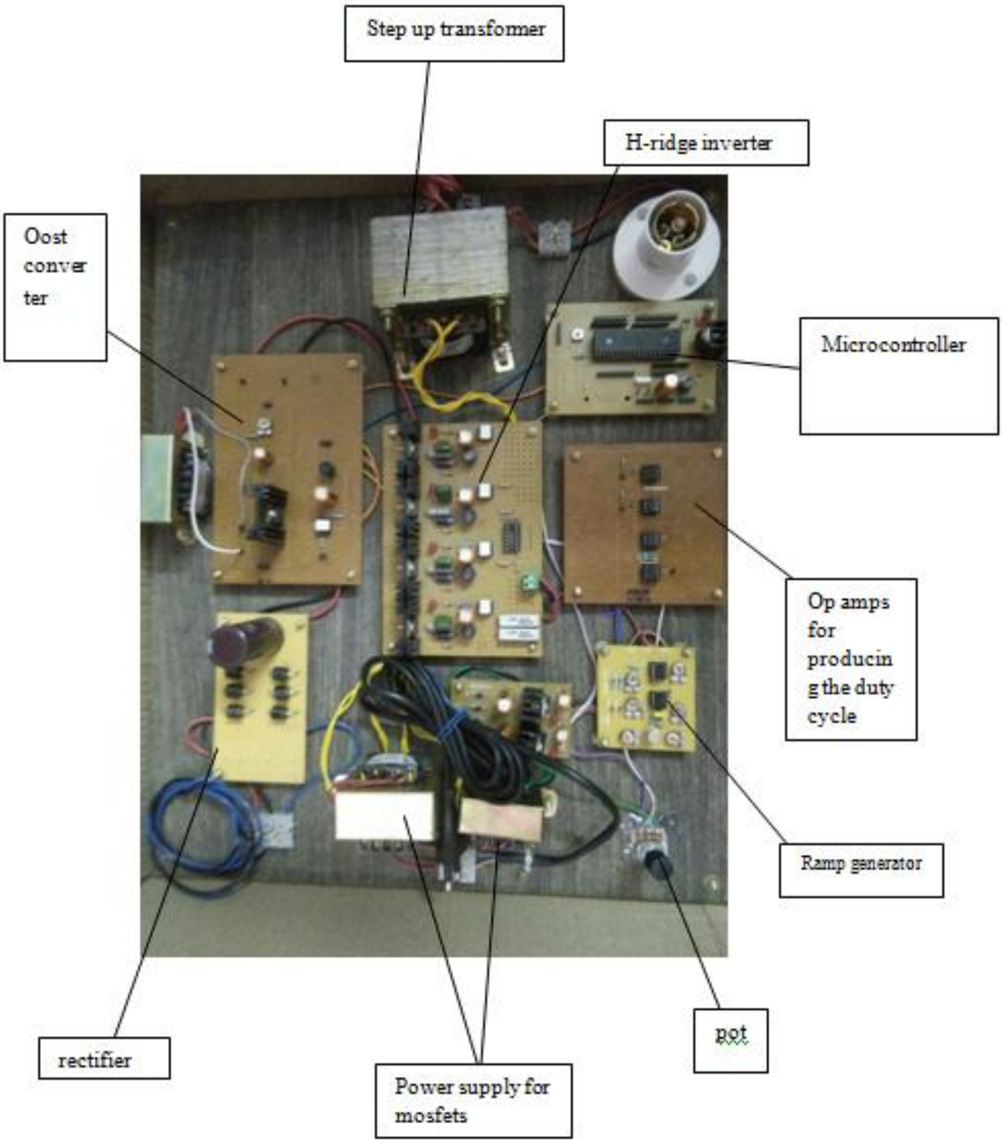


Fig 5. 3-phase load obtained oth on the d and q axis, and DC link voltage required for controlling method.

IV. Experimental results



The model of the control method is done using the PIC microcontroller, rectifier, boost converter and the H-bridge inverter for only the single phase operation on a small load. Here, instead of the wind turbine and the permanent magnet synchronous generator, the single phase auto-transformer is used for producing the variable voltage and given to the rectifier.

The digital output is obtained using the CRO, the input for the CRO is obtained from the pot as the sinusoidal waveform is compared with the ramp wave generated using the ramp generator and the comparison results are automatically adjusted to the constant voltage as stored in the microcontroller. Thus the figure shown is used to control the wind turbine according to the wind speed.

V. Conclusion

The control strategy for small wind turbine during high wind speed regions is implemented in both simulation and also as the experimental model. The simulation results for the 3-phase grid connections are shown above in fig 4 and 5. This control method is effective only for the 3 phase grid tied operation and less effective in the single phase operation.

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