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Simulation of PMSG based wind energy conversion system using MPPT

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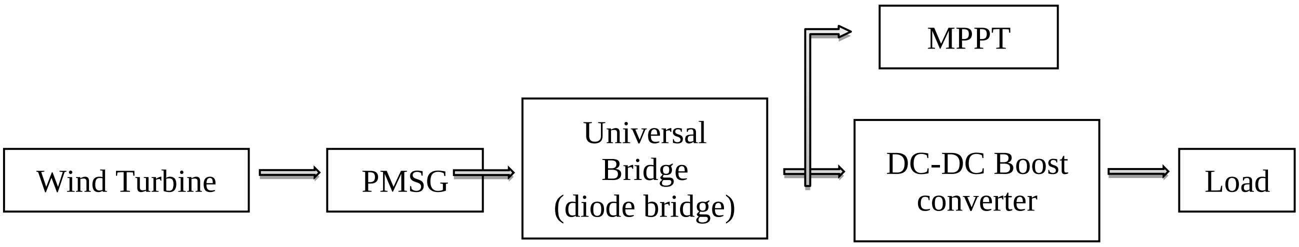
Abstract: In this project a model of a wind turbine using a permanent magnet synchronous generator (PMSG) is presented and the control schemes are proposed. The model presents the Maximum Power Point Tracking(MPPT) algorithm used to extract maximum power from a PMSG direct driven Wind Turbine. The DC-DC boost converter has been used to boost up the low AC voltage generated by the PMSG directly driven by the Wind Turbine.

KeyWords:- Wind Turbine, Permanent Magnet synchronous generator(PMSG), Maximum Power Point Tracking(MPPT), Universal Bridge, DC-DC boost converter, Perturb and Observe Control(P&O), Wind Energy Conversion System(WECS)

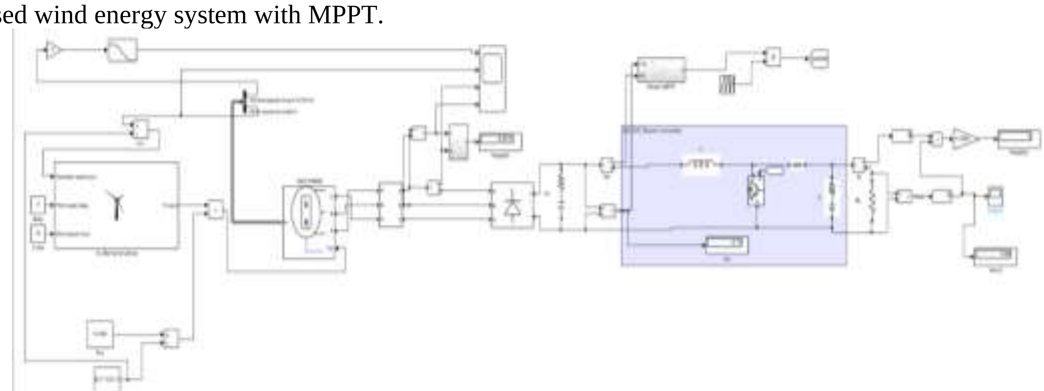
I. INTRODUCTION

In recent years, the use of renewable energy resource is increased due to increasing demand of power and depletion of fossil fuel such as coal for electricity generation. Moreover, the issue of climate change are causing concern and hence many regulations are proposed to reduce the Carbon dioxide (CO2) emission. Among the renewable energy, solar energy and wind energy is more utilised because of its abundant availability everywhere. The Wind Energy is gaining interest because of technology enhancement and significant power cost reduction.More effective control strategies are under research in order to obtain reliable, cost effective and quality power from the wind. As Permanent Magnet Synchronous Generator (PMSG) is most preferred wind generator due to its reliability and size for stand-alone wind energy conversion system.MPPT control algorithms can be employed in order to capture the maximum power from available wind by maintaining the optimum steady voltage across the load.



II. MODELLING OF WIND ENERGY CONVERSION SYSTEM

The simulation models of wind turbine, PMSG and power electronics converters which comprises the whole WECS system are explained in this section. We will discuss the application of MPPT in wind energy generation system. A 12.3 kW Wind turbine and a PMSG machine will be used. We will not use any drive train, so this will be direct driven PMSG based wind energy system with MPPT.



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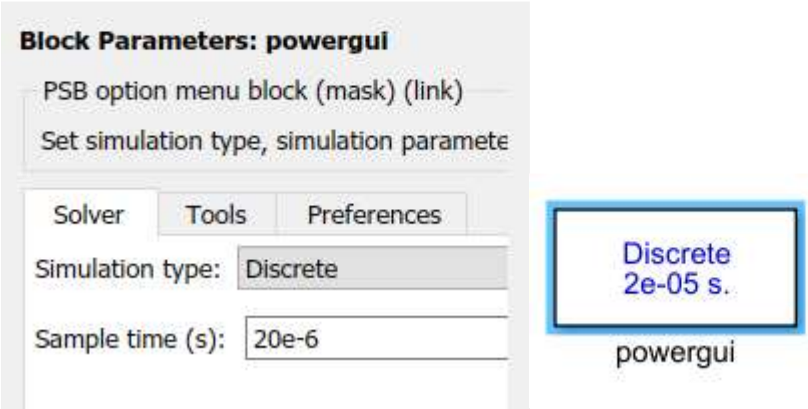
II.1 SOLVER AND POWERGUI

The solver type will be fixed-step, solver will be Runge-Kutta and fixed step size will be 10e-6. We will use Powergui as my entire work will be on Powergui and simulation type will be discrete and sample time will be 20e-6.



II.2 WIND TURBINE

The mechanical power, Pm captured by theturbine is given by the equation

$P_m = ½\, C_p(\beta,\lambda)\rho\pi R^2\, V^3_{WIND}$ (1)

Where Cp is a rotor power coefficient,
β is blade pitch angle,
λ is a Tip Speed Ratio (TSR),
ρ is air density,
R is radius of wind turbineblade
And V_{wind} is the wind speed.
The rotor power coefficient is defined by the fraction of available wind power that can be transformed to mechanical power. Cp depends on the blade aerodynamics, which is the function of β and λ . The power coefficient of turbine is determined by TSR. Cp and TSR is determined by the shape of the blade. However, Cp in general blade design is assumed for simplicity.

$C_p=(0.44-0.0167\beta)\sin[\pi(\lambda-2)/130.3\beta]-0.0018(\lambda-2)$(2)

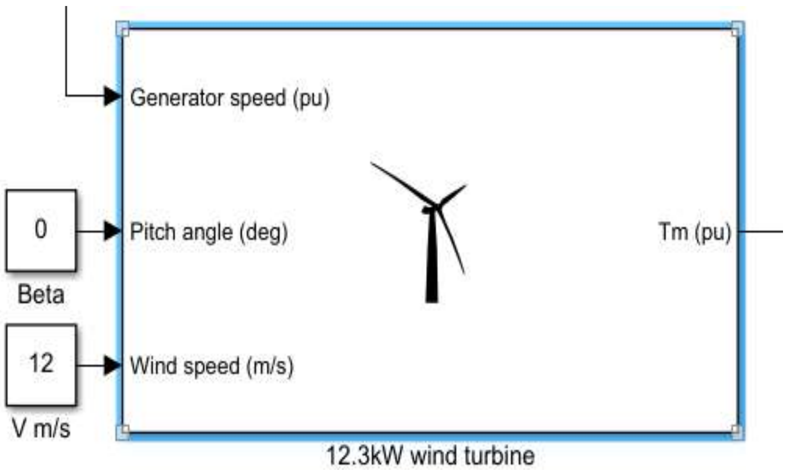
The TSR (λ) can be defined as the function of a wind speeds.

$\lambda=\omega_m R/ V_{wind}$(3)

where, ω m is the rotor speed of a wind turbine. The input torque for the generator is obtained from the formula:

$T_{m=} P_m/\omega_m$ (4)

From the above equation it can be determined that the performance of the wind turbine is highly dependent on the wind speed.



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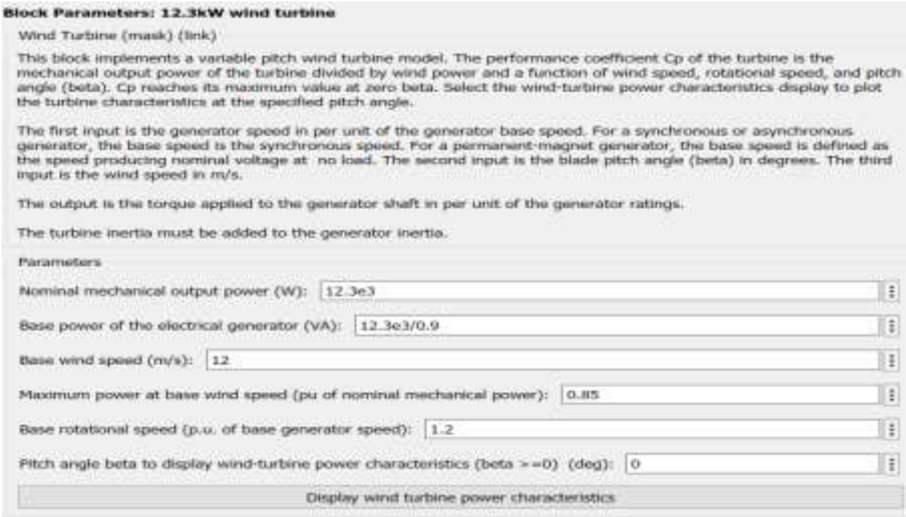


II.3PMSG

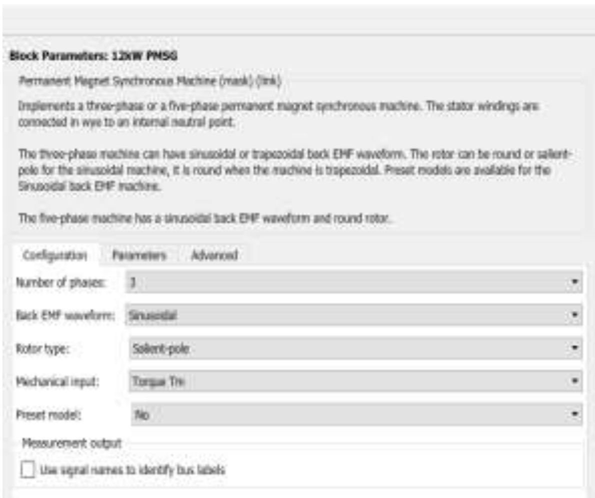
PMSG is widely used for stand alone small wind turbines because they have high efficiency and less maintenance. The PMSG is modelled in dq reference frame. Both d and q axis contain a voltage induced by the armature. The generator is implemented with DC Voltage and current. The current of d axis and q axis is determined by the equation 5 and 6 respectively

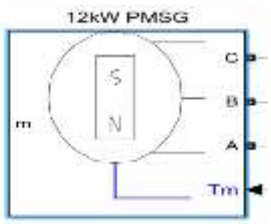
$di_{sd}/dt=-R_{sa}/L_{sd}\, i_{sd} + \omega s L_{sq}/L_{sd}\, i_{sq} + 1/L_{sd}\, u_{sd}$ (5)

$di_{sq}/dt= -R_{sa}/L_{sq}\, i_{sq} - \omega s\, (L_{sd}/L_{sq}\, i_{sd} + 1/L_{sq}\psi\, p) +1/L_{sq}\, u_{sq}$ (6)

The electromagnetic torque obtained from the rotor of PMSG is given by the equation 7
$Te=1.5\, P/2[\psi_p i_{sq}+i_{sd}i_{sq}(L_{sd}-L_{sq})]$ (7)

Where, i_{sd}, i_{sq} , u_{sd} and u_{sq} are the currents and voltages of d and q axis respectively. ωs is the angular frequency of the generator. L_{sd} and L_{sq} are the inductance of the generator. ψ_p is the permanent flux, R_{sa} is the resistance of the stator and P is the number of poles





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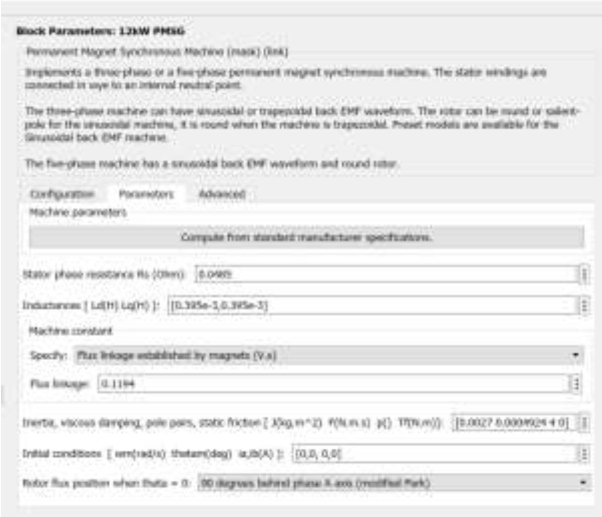
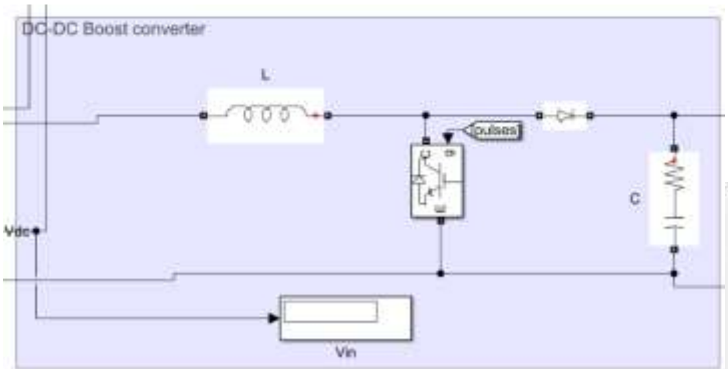


II.4 **Modelling of DC/DC Converter**

The DC-DC converter employed here is Boost converter is used to step up the input DC voltage. By varying the duty cycle the output voltage can be controlled. This converter regulates the input voltage through the switch to reach the reference voltage which consists of maximum power Boost converter operates in mainly two different mode

Mode I : Switch is ON, Diode is OFF

Mode II : Switch is OFF, Diode is ON



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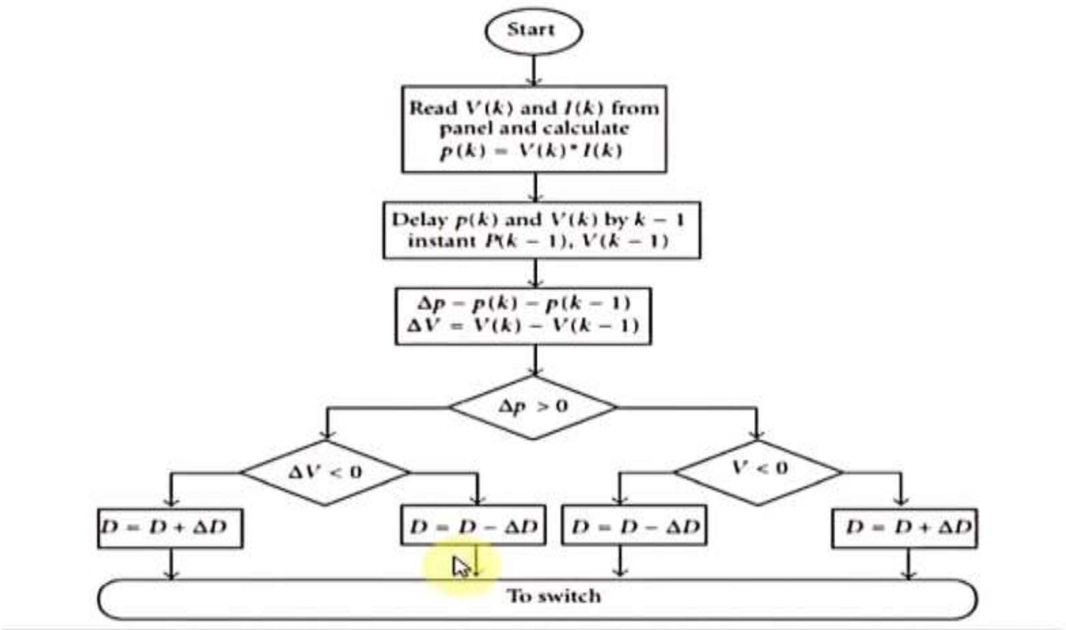
III.CONTROL STRATEGIES OF WECS

The MPPT based control strategy is used here to obtain the maximum power. Wind energy even though available in abundant, the wind speed varies rapidly. The efficiency of the WECS depends upon the accuracy in which the maximum power is extracted by the MPPT controller.The PMSG based MPPT control mainly focus on converting variable voltage and frequency to fixed voltage and frequency. The most commonly used power electronics converter configuration is analysed in this paper three MPPT techniques such as conventional PI controller, P&O method and FLC MPPT method are utilized and comparative study is done to choose the efficient and appropriate MPPT technique so that the maximum power is extracted from the available wind. In this project P&O MPPT method is used to extract maximum power from the available wind.

Perturb and Observe Control

The P&O method is used to search for the maximum optimal point for the given wind speed. The P&O method does not require any prior wind turbine knowledge. It is independent, flexible and simple technique. Here the P&O method uses the perturbed output voltage across the load to determine the optimal operating point that will extract the maximum power. If the power of the current cycle is greater than the previous one then the voltage is modified in same technique as the previous one. Whereas, if the power is lesser than the previous technique the voltage must be varied in the opposite direction. The only disadvantage of P&O technique in wind energy conversion is that they cannot track the rapid variation of the wind speed thus affecting the efficiency of the overall system and the speed of convergence. The flow chart of P&O method is described:



IV. RESULTS AND DISCUSSION

The detailed implementation of PMSG based WECS using boost converter incorporated with P&O controller in MATLAB/ Simulink is shown in Fig.

For the calculation of DC-DC boost converter following Live Editor program is used:-

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Live Editor - D:\Mission_SCI\ForYouTube\CalcultionOfBoostConverter.mlx *

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```
Vinmin=50; % minimum out voltage available at rectifier output
Vout=400;  % DC-DC converters output
Po=12000;  % The power rating of the DC-DC converter
% The switching frequency (fs)
fs=20000;
% The efficiency(n) of the DC-DC converter
n=0.95;

D=(1-(Vinmin*n)/Vout); % D is the dutycycle of the DC-DC boost converter
Io=Po/Vout;
% input current ripple (dI)
Ioriple=0.2; % 20%-40% of the output current
dI=Ioriple*Io*(Vout/Vinmin);
% Output voltage ripple(dV)
% I am considering 0.5% voltage variations in output voltage,
% standard is 0.5%-1%.

dV= Vout*0.5/100;
% the inductance value (L)
L=((Vinmin)*(Vout-Vinmin))/(dI*fs*Vout);
% the capacitance value(C)
C=(Io*D)/(fs*dV);

% Minimum load to be applied more then of
RL=(Vout/Io);
```

pmsg pro.mat (MAT-file)

Name	Value
C	6.6094e-04
D	0.8813
Io	30
Ioriple	0.2000
L	4.5573e-05
Po	12000
RL	13.3333
Vinmin	50
Vout	400
dI	48
dV	2
fs	20000
n	0.9500
vinmin	50

S. No.	R load	Vin	Vout	Pac	Pdc
1.	13.5	55.87	281.33	7.163	5.863
2.	13.33	-0.17	0.00	0.4375	2.068e-20
3.	54	79.91	398.18	5.918	2.936
4.	56	4.77	0.00	0.4822	0

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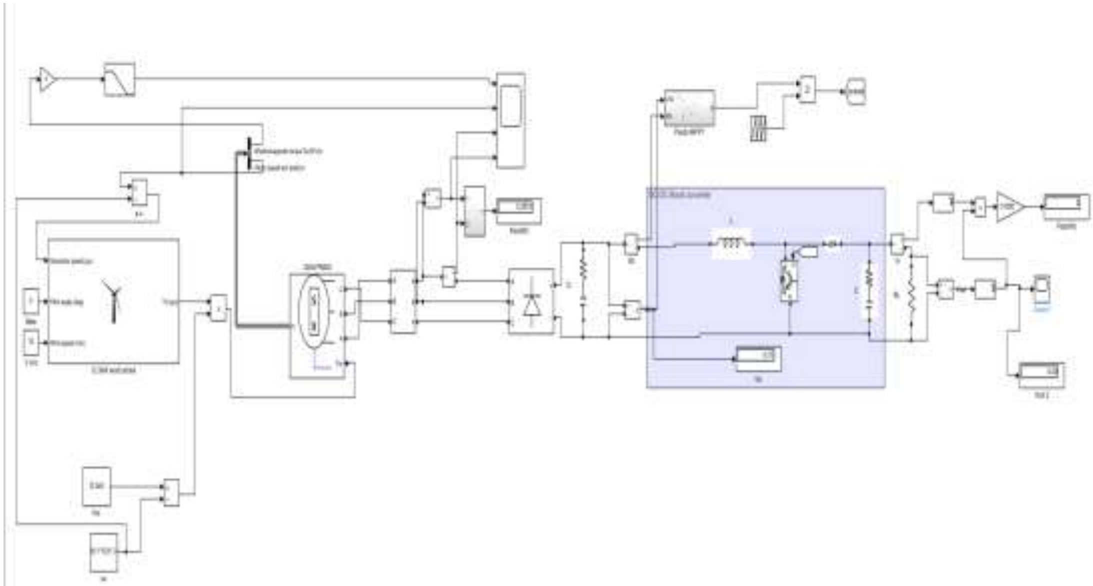

The MPPT achieved will be at R_{load}=54.66 at Vout =400.

V.CONCLUSION

In this project, MPPT controllerP&Ocontroller is modelled and the output is compared for wind energy under varying loadcondition. The performanceofcontroller is analysed, and it is verified that controller is more efficient and reliable the P&O based technique is suitable for the condition where the system is stable of with minimum variance. Wind Speed being high non-linear the P&O algorithm oscillates around optimal point thus making it difficult to track the next pointit is concluded that the P&O based MPPT method is the best option for stand-alone WECS.

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