Permanent magnet synchronous generator Based on wind energy conversion system

By

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Abstract:

The presented work proposes a suitable power converter design for a Wind Energy Conversion System (WECS) connected to a constant speed Permanent Magnet Synchronous Generator (PMSG) for MPPT. In the present work energy is derived from WECS and fed to the PMSG. The output of the generator is rectified using an uncontrolled three phase diode-rectifier and a constant value is achieved using a open loop DC-DC converter. In order to enhance the efficiency of a wind energy conversion system (WECS), the maximum power point tracking (MPPT)simulation algorithm is usually employed. This paper presents an optimal algorithm to extract the maximum available power under a constant wind speed , which is applied in a permanent magnet synchronous generator (PMSG)-based WECS.The algorithm that is used in this project is Perturb and Observer. Here we are open loop control because we are considering wind speed as constant.Simulation of proposed scheme is presented by MATLAB-Simulink model and the results demonstrate the validity of the developed modelThe whole system is simulated using MATLAB/ Simulink and the results are presented to demonstrate the veracity of the developed control scheme.

Keywords: WECS- Wind Energy Conversion System; PMSG- C; MPPT-
Maximum Power Point Tracking; DC-DC Boost Converter

Abbreviations:

Abbreviation	**Description**
WECS	Wind Energy Conversion System
PMSG	Permanent Magnet Synchronous Generator
MPPT	Maximum Power Point Tracking
DFIG	Doubly Fed Induction Generator

Introduction:

Nowadays, PMSGs are most popular for power-generation, as they have high efficiency. For instance, the electrical efficiency of PMSGs is higher than the synchronous-generators (SG's) in the moderate-size power marine diesel generator-sets. As PMSG don't comprise excitation control, voltage-regulation is island-operation is challenging. The flux-density of permanent magnet (PM) reduces with the rise in temperature, so voltage-control become complicates. Some of the difficulties of PMs are high cost and handling while manufacturing. The variable-speed operation of the WECS is essential for extracting maximum wind power.But here we are doing for constant speed for MPPT. A modern control based tracking of power or torque helps to achieve best utilization of wind-energy. Control strategies are developed based on wind-velocity to acquire required shaft speed. These schemes involve high cost and reduced reliability for a small scale WECS. For standalone operation, load-side converter voltage needs to be controlled in terms of amplitude and frequency. Grid connected PMSG based WECS are also proposed and implemented. Probability to attain less pole-pitch permits the machine to run at low speed and removes the gearbox or allows using single-stage gear for more compact design. This project reviews various PMSG techniques with the aim of maximum power

generation.

Wind energy conversion systems have been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. The amount of power output from a wind energy conversion system (WECS) depends upon the accuracy with which the peak power points are tracked by the maximum power point tracking (MPPT) controller of the WECS control system irrespective of the type of generator used. This study provides a review of past and present MPPT controllers used for extracting maximum power from the WECS using permanent magnet synchronous generators (PMSG), squirrel cage induction generators (SCIG) and doubly fed induction generator (DFIG). It is direct driven permanent magnet synchronous generator.

MAXIMUM POWER POINT TRACKING:

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used. The maximum power extraction algorithms researched d so far can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. Maximum Power Point Tracking (MPPT) is essential for the Wind Energy Conversion System (WECS) mainly for the small scale wind turbine. In order to captured the maximum possible power from wind turbine, it is very important to operate the WECS at MPPT and tracking the maximum power point in the power output signal.

The Wind turbine can produce maximum power at a particular operating point called Maximum Power Point (MPPT).To produce maximum power and to get maximum efficiency, the wind turbine must operate at this particular point. This proposed method has the ability to track the MPPT for the extreme environmental condition, e.g.,large fluctuations of wind speed and here considering constant speed of wind turbine. The algorithm is simple , can be computed very rapidly and it is open loop control system. It is normally employed in conjunction with the power converter (dc–dc converter and/or inverter). However, due to the varying environmental condition,the power– voltage characteristic curve exhibits a maximum power point (MPPT) that varies non-linearly with these conditions—thus posing a challenge for the tracking algorithm.The MPPT is responsible for extracting the maximum possible power from the wind turbine and feed it to the load via the buckboost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point tracking.

WIND TURBINE:

Non-conventional means of energy has become an alternative and or an additive for the conventional source of energy. With endless potential of wind energy and environmental-merits, it has become the most popular source of renewable energy. The WECS based on the wind-turbine (WT) is categorised as fixed and variable speed system. Initially fixed-speed WECS was popular one. Nowadays, variable speed generators are more effective. PMSG is more effective and efficient as compared to other generators and are best suited for WECS due to its high torque to size ratio, less maintenance required, omission of slip-rings, reduced overall-cos. Permanent magnets(PM) instead of electromagnets makes the stator direct-flux constant . The modelling of wind based power generation system is discussed below.

The rotor-blades of WT converts the kinetic-energy of the wind into mechanical-energy. Then generator as an electrical-sytem transform mechanicalpower into the electrical-power. WTs generally used for WECS are verticalaxis-wind-turbine (VAWT) and horizontal-axis-wind-turbine (HAWT). HAWT shows listed below advantages than VAWT.

It offers flexible blade-pitch so that blades can operate at optimum-angle of attack, for extracting more wind-energy. it always captures efficient windenergy from during the whole rotation as blade’s rotation is perpendicular to the wind. it is self-starting, but VAWT needs initial starting-torque.

PROPOSED MODELS

MODELLING OF WIND TURBINE:

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The kinetic energy, which is extracted from the wind, is penetrated on to the turbine blade area.

According to the principle of energy-mass conservation in wind, the maximum extracted wind power is given as ;

Pwind= 1/2 Av3w (1)

Where vw is wind velocity, is density of air,A is swept-area of turbine-blades.

Cp, power coefficient is defined as the ratio of turbine power to the extracted wind power.

Cp= Turbine power (Pturbine)

Power obtained from wind (Pwind) Hence the turbine-power is given by:

Pturbine= PwindCp= 1/2Av3wCp (2)

The turbine-power wrt wind transients is given by

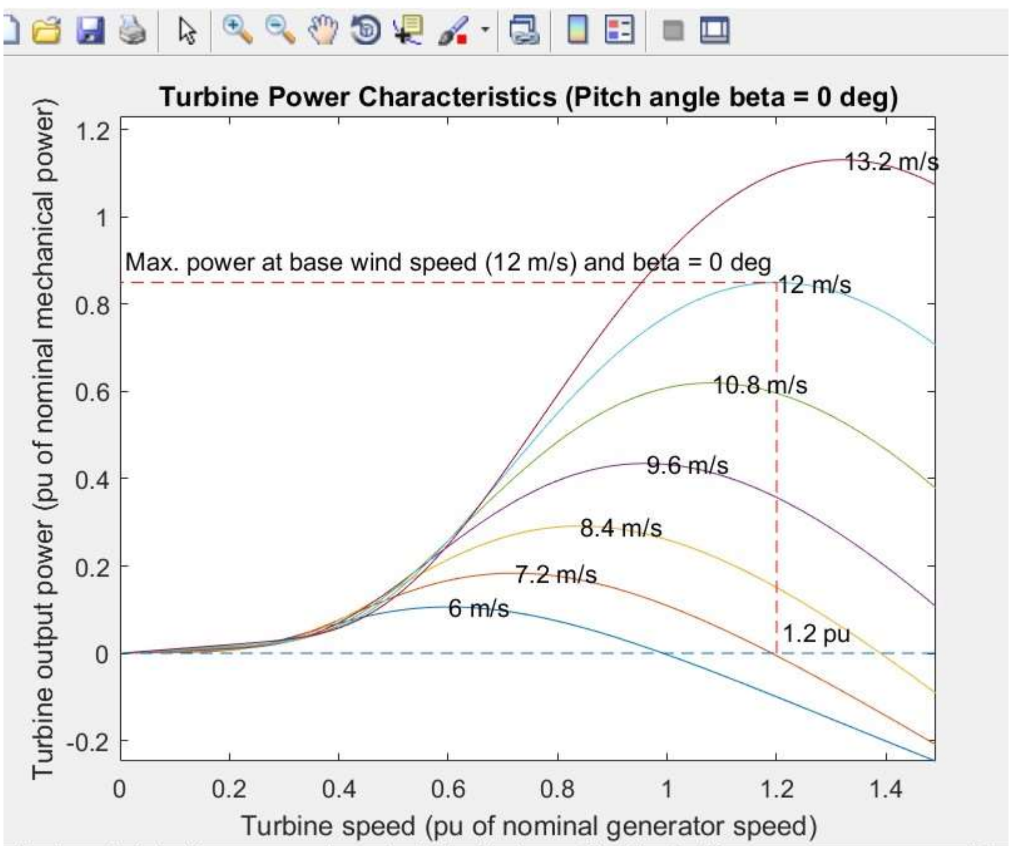
Pturbine= PwindCp= 1/2Av3wCp (,) (3)

Where is the tip-speed ratio of the turbine:

= rotational speed of rotor (r) radius(r)/wind velocity (vw) (4)

Where Cp (,) =C1 (C2 i C3C4) e C5/ i + C6

In this project we used 12.6kW wind turbine of radius 1.3m,pitch angle is zero, the speed of the turbine is considered as 12m/s and the tip speed ratio is 8.1.



Turbine power characterstics

PMSG MODEL:

figure 2 shows the d-q axes 'park' model. In PMSG rotor is made up of PM,not fed by external source for producing magnetic-field. Hence rotor voltageequation need not be be developed as variation in rotor flux wrt time is not there.

Stator voltageiequations are as follows:

Vsd = RsIsd + ds/dt esq

Vsq = RsIsq + dsq/dt + esd

The stator fluxes are given by,

sd = LdIsd + m

sq = LdIsq + m

Where, Rs = stator-winding resistance, Ld = d-axis stator-inductance, Lq = q-axis stator-inductance, m = flux linkage, Vsd Isd = d-axis stator voltage current, Vsq Isq = q-axis stator voltage current.

From above Equations:

Vsd = RsIsd + LddIsd/dt eLqIsq

Vsq = RsIsq + LqdIsq/dt + eLdIsd + em

The electromagnetic-torque can be written as:

Te = 3/2 P(mIsq + (Ld Lq)IsdIsq)

For surface-seated PMSG, we can assume Ld = Lq. Then Te can be written as:

Te = 3/2 P (mIsq)

Power Generation Using Permanent Magnet Synchronous Generator (PMSG) For steady-state condition, real power Ps and reactive power Qs of PMSG are as follow:

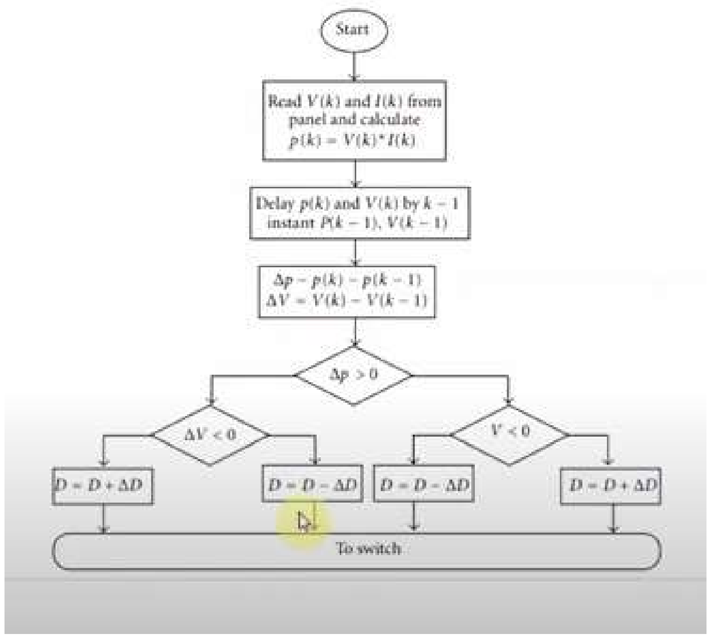
Ps = VsdIsd + VsqIsq

Qs = VsqIsd VsdIsq

MPPT:

The Perturb and Observe (PO) has been implemented to extract maximum power at each instant and summarizes the control action of the PO method. The flowchart of the implemented algorithm is shown. The operating voltage is perturbed with every MPPT cycle. As soon as the MPP is reached, it will oscillate around the ideal operating voltage. For example, if the controller senses that the input power increases (dp¿0) and the voltage (dV¡0), it will decrease (-) Vref to bring it closer to the MPPT.

The MPP algorithm PO is widely used, due to its ease of implementation and its low cost. It is based on the following criterion:, if the operating voltage of the generator voltage is perturbed in a given direction and dp/dV¿0, it is known that the perturbation moved the operating point towards the MPP, the PO algorithm would then continue to perturb the generator voltage in the same direction. Otherwise, if dp/dV¡0 then the change in operating point moved away from the MPP, and the PO algorithm reverses the direction of the perturbation. In other words, the system works by increasing or decreasing the operating voltage and observing its impact on the output power.



DC-DC BOOST CONVERTER:

Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it ”steps up” the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current. The Vout of the converter is 400V. The efficiency of the converter is considered to be 0.95. The switching frequency of this converter is 20khz and the power rating of the converter is 12000W

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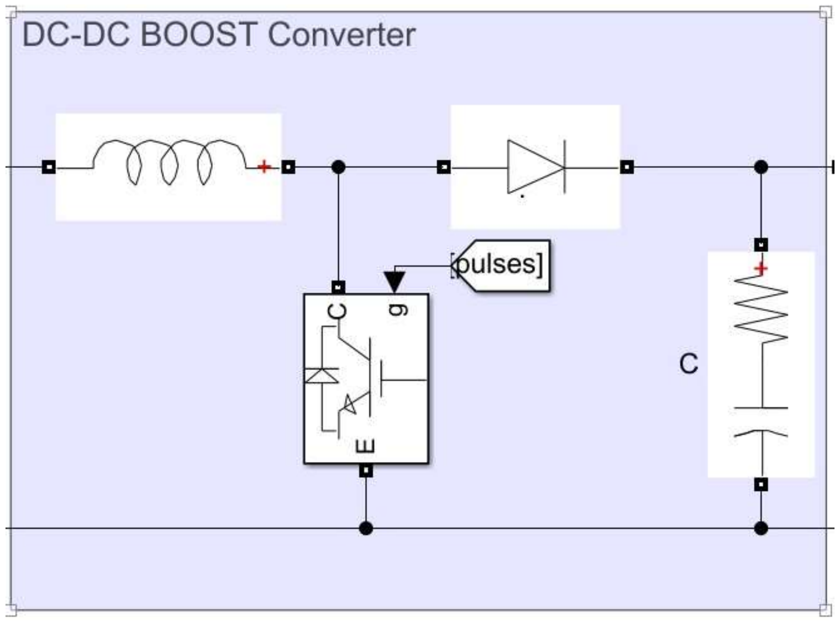
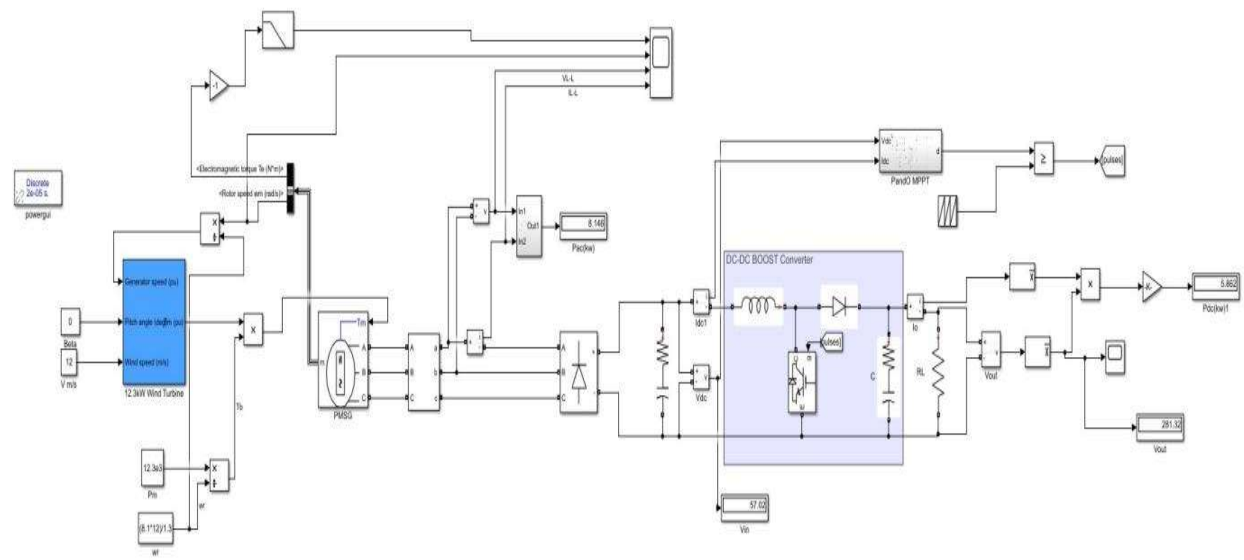


Circuit of DC-DC BOOST Converter

SIMULATION:

The model shown in Figure represents a block diagram of a wind turbine connected to a resistive load through a dc/dc boost converter with MPPT controller. Block diagram of a wind turbine connected to a permanent magnet synchronous generator connected to the load In the model.The wind turbine of constant speed as a constant dc source created using the subsystem block from Simulink library browser, which included all functions wind turbine such as torque generation connected to PMSG. The model has a input of constant wind of speed 12m/s and pitch angle is considered as 0. This model generates current and receives voltage back from the circuit tracking Algorithm.



Simulation Circuit

DC-DC BOOST CONVERTER PROGRAM:

Vinmin=50; minimum out voltage avaialable at rectifier output

Vout=400; DC-DC converter output

Po=12000; the power rating of the DC-DC converter fs=20000; the switching frequency of the DC-DC converter

n=0.95; the efficiency of the DC-DC converter

D=(1-(Vinmin*n/Vout)); D is the duty cycle

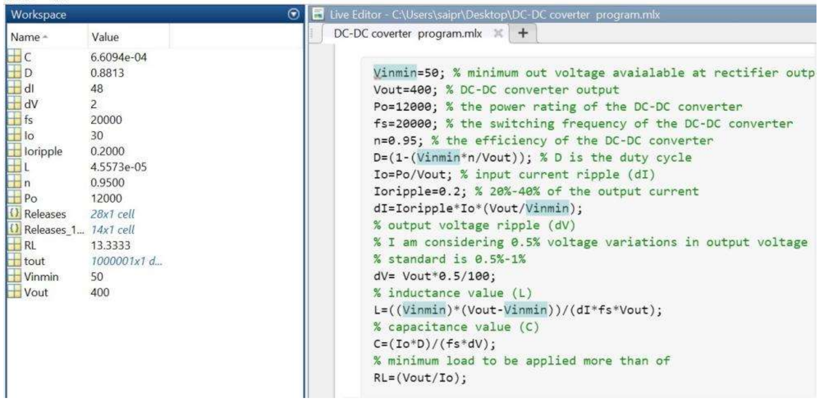
Io=Po/Vout; input current ripple (dI) Ioripple=0.2; 20-40 percent of the output current dI=Ioripple*Io*(Vout/Vinmin); output voltage ripple (dV)

I am considering 0.5 percent voltage variations in output voltage standard is 0.5 dV= Vout*0.5/100; inductance value (L)

L=((Vinmin)*(Vout-Vinmin))/(dI*fs*Vout); capacitance value (C) C=(Io*D)/(fs*dV);

minimum load to be applied more than of

RL=(Vout/Io);



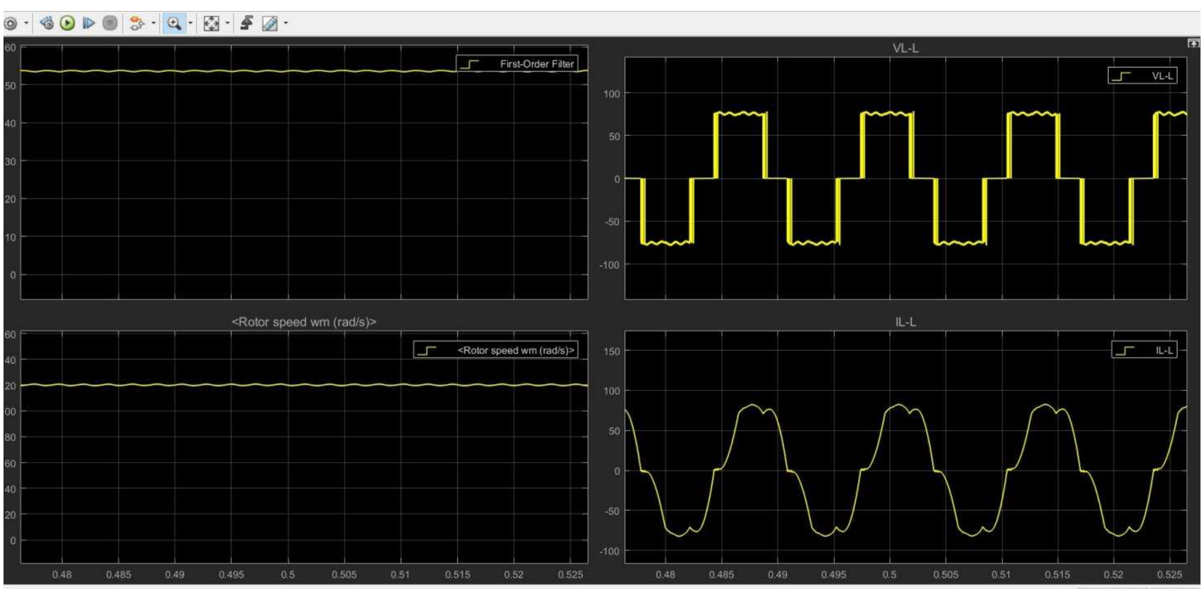
Program and output for DC-DC BOOOST CONVERTER CIR-

CUIT PARAMETERS

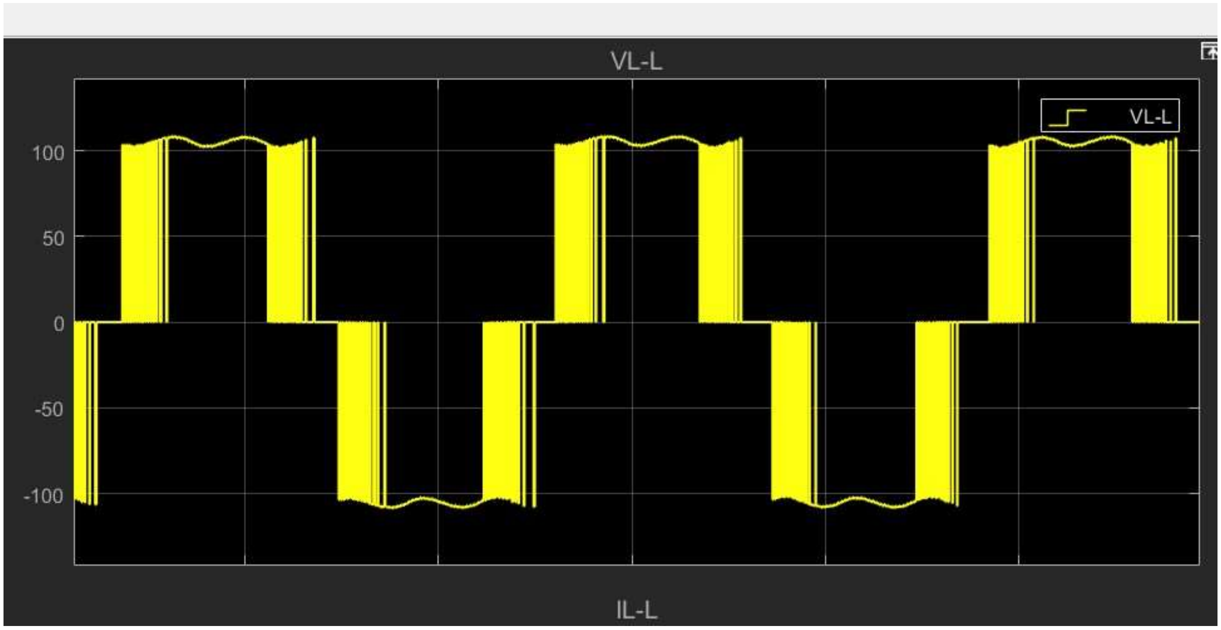
OUTPUTS OF THE SIMULATION SYSTEM:

It is the voltage and current produced after the wind energy is converted to electrical energy and send through 3 phase V-I measurement and Vline and Iline is measured.

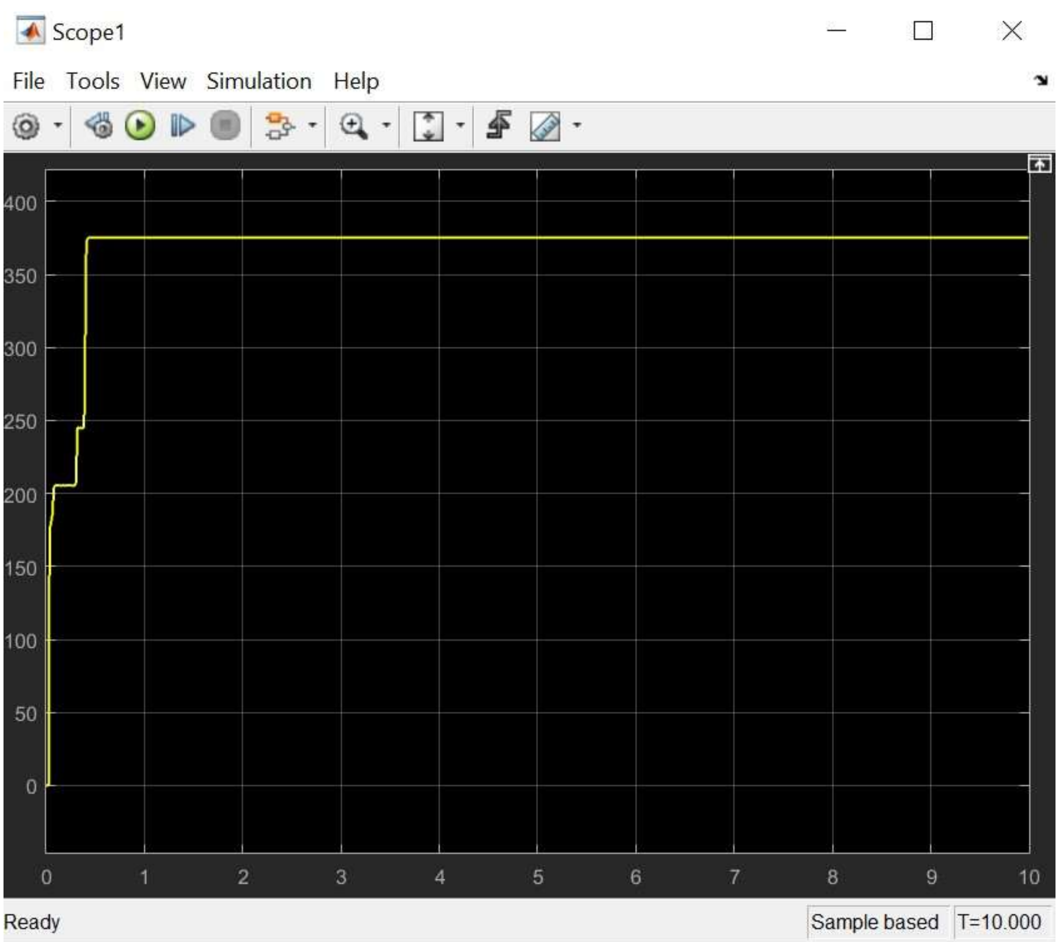
Here the maximum power point is observed by changing the load of the system, but here the minimum load required to operate the system that is more than 13.33.



The wind speed and volatage and current across pmsg



Voltage graph of PMSG



Voltage across DC load of the system

CONCLUSION:

In this project, PMSG topologies such as with controlled stand-alone operation, different control algorithms, and optimization technique for PMSG have been discussed based on their maximum power generation. Each technique is determined according to the required specification in terms of the parameters used. Also, comparative analysis of various PMSG based constant-speed WECS techniques is studied with advantages and future recommendations.The performance measure of PMSG can be enhanced by adopting several control mechanism with the aid of advanced optimization techniques. This research study helps as an advantageous knowledge for future research direction.In this thesis, several important control algorithms for the wind turbine PMSG systems were studied and analyzed. In order to further validate the control methods, the control algorithms were applied to a case study 12.6kW wind turbine PMSG system and a simulation study was performed in this thesis.

For the generator-side converter control, the optimal tip-speed ratio based MPPT control algorithm and vector control method were applied. From the simulation results, the MPPT method has shown the capability of controlling the wind turbine PMSG to generate the maximum power at different load. Here we donot require any drive train because it is a direct driven system.(no gearbox which will reduce the wear and tear of the of the machine).Here ,various PMSG topologies with simple control algorithms, and optimization technique for PMSG have been discussed based on their maximum power generation. The performance measure of PMSG can be enhanced by adopting several control mechanism with the aid of advanced optimization techniques. This research study helps as an advantageous knowledge for future research

direction.

i) A method of employing modified PO algorithm has been validated for maximum power point tracking of a wind energy conversion system.

ii)The algorithm works properly and increases the efficiency of the system while being used in conjunction with DC Link. iii)Duty cycle of boost converter has been varied using Modified PO algorithm for maximum power point tracking.

iv)Waveforms for power output, voltage and current clearly indicate that that enabling of MPPT increases the efficiency and also improves the stability of the system.