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Modeling and Simulation of Grid Connected 10 Mw PMSG Based Wind Energy Conversion System

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ABSTRACT: This project develops the mathematical model of a permanent magnet synchronous generator (PMSG), which is designed for a direct-driven 10MW wind turbine, and its corresponding simulation model for the control of the PMSG for grid connection using MATLAB/Simulink. The model includes sub-modules, such as a model of the wind speed, a model of the PMSG, model of wind turbine, turbine rotor, Phase Lock Loop (PLL),Pitch controller, grid side converter system, machine side converter system, crowbar protection system. The machine side converter is used to extract maximum power from the wind. PMSG convert the mechanical form of wind energy into electrical energy. Then generator side converter convert AC current into DC then a dc-link connected between two converter. Grid side converter or inverter converts DC current into AC current. This AC current sent to the national grid. 10MW wind turbine connected to a 25kv distribution system exports power to a 120 kv grid through a 30 km, 25 kv feeder. Then a filter is connected between inverter and grid. Crowbar also protect the whole system.

This paper systematically analyses the mathematical model along with its sub-modules, and creates simulation models using MATLAB/Simulink. The simulation results demonstrate that both the mathematical model and simulation model are correct, and the parameters of the generator output are synchronized with the main grid

KEYWORDS: Permanent magnet synchronous generator(PMSG), wind energy conversion system(WECS), back to back PWM converter IGBT based, DC link capacitor, Direct-Driven, MPPT controller, PLL loop, generator side converter control, grid side converter control, pitch controller, crow bar protection and transformer.

I. BACK GROUND

Electrical and electrical vehicles, which are considered as the best replacement of conventional fossil fuel internal combustion engine based vehicles, have been greatly evolving and significantly commercialized during the recent years. Accordingly, there will be a growing demand for electrical energy when these vehicles became a part of the electrical grid load. Conventional electrical energy sources depend heavily on fossil fuel burning. However burning of fossil fuels causes environmental issues such as global warming, acid rain and urban smog etc. by releasing carbon dioxide, sulfur dioxide, and other pollutant in the atmosphere. Based on the issue, the renewable energy, which include photovoltaic energy, wind energy and geo thermal energy etc has been heavily investigated and rapidly developing. Renewable energy has the advantages that it is abundant, clean and becoming increasingly economical. In fact renewable energy sources help in reducing about 70 million metric tons carbon emission per year that would have been produced by fossils fuels. In recent years, the electrical power generation from renewable energy sources, such as wind, is increasingly attraction interest because of environmental problem and shortage of traditional energy source in the near future. Among various types of energy sources wind energy is fastest growing renewable energy sources.

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Nowadays, the extraction of power from the wind on a large scale became a recognized industry. It holds great potential showing that in the future will become the undisputed number one choice form of renewable source of energy.

II. INTRODUCTION

In wind energy conversion systems (WECSs), the key technologies include wind turbine technology, permanent magnet synchronous generator (PMSG) modeling technology, power electronics technology and system control technology. For the wind turbines, based on the orientation of the rotation axis of the wind turbine, there are horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). Compare to the vertical-axis wind turbine, horizontal-axis wind turbine have higher wind energy conversion efficiency, which is widely applied in wind energy industry. The wind turbine can also be classified as fixed-speed wind turbine and variable-speed wind turbine. The fixed-speed wind turbine possess the merit that they are simple, robust and require lower construction and maintenance cost. As the large wind turbine (up to 10MW) attract more and more attention nowadays. In this paper, the control algorithm of direct-driven wind turbine PMSG system are studied and simulated. The direct-drive wind turbine PMSG do not have the gearbox between the wind turbine and rotor shaft, which avoid the mechanical power losses caused by gearbox. Moreover the removal of gearbox also helps in reducing the cost of the system. The kinetic energy in the wind is converted into mechanical energy by the turbine by way of shaft and gearbox arrangement because of the different operating speed ranges of the wind turbine rotor and generator. The generator converts this mechanical energy into electrical energy. However, as wind is an intermittent renewable source, the wind source extracted by a wind turbine is therefore not constant. For this reason, the fluctuation of wind power results in fluctuated power output from wind turbine generator. From the point of view of utilities, due to the fluctuation of generator output, it's not appropriate for the generator to be directly connected to the power grid. In order to achieve the condition that the generator output power is suitable for grid-connection, it is necessary to use a controller to manage the output produced by the wind turbine generator.

III. WIND TURBINE MODEL

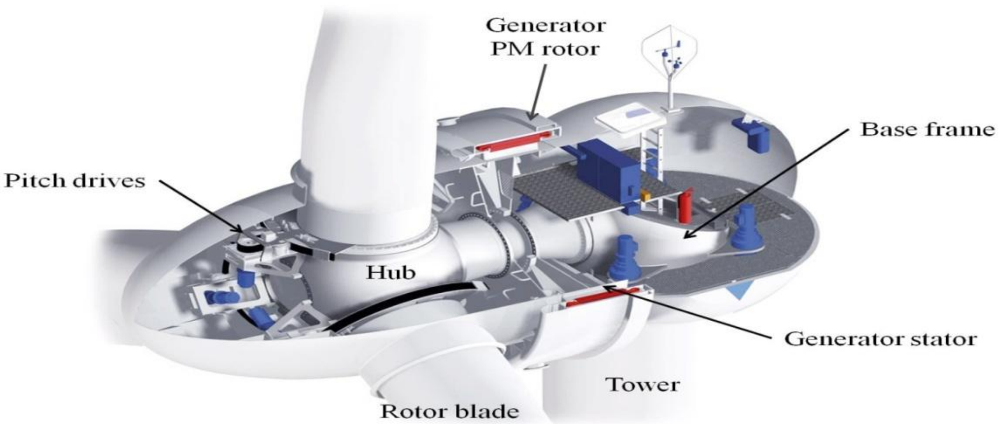

Fig.1.Wind Turbine Modelling

IV. MODEL OF PMSG WIND TURBINE

(A) PMSG Wind Turbine basic structure : The basic of PMSG wind turbine structure shown on Figure 2. The wind turbine generates torque from wind power.

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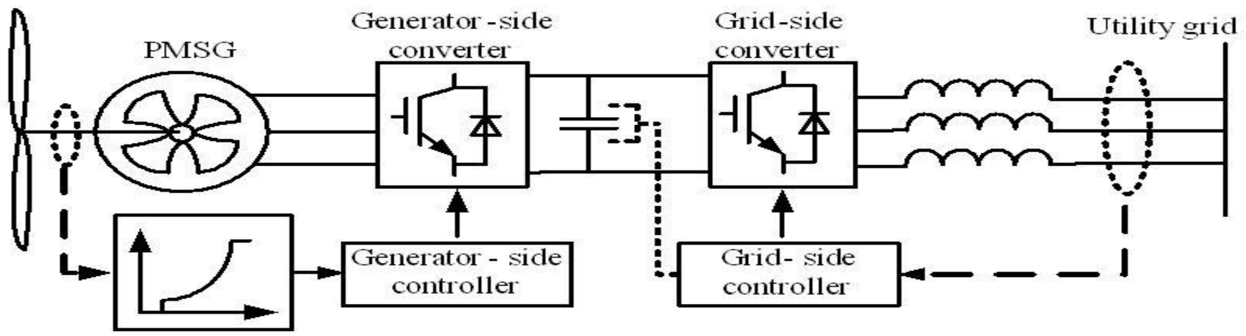

Fig-2.General wind turbine PMSG system with control schemes

(B).Model of Wind Turbine: The wind turbine analyzed is discuss below-

$$P_m = C_p(\lambda,\beta)\frac{\rho A V^3}{2}$$

Where, ρ - air density

V – Wind Speed

Cp - Coefficient of Performance (or Power Coefficient) of the wind turbine

A – Area swept by the rotor blades of the wind Turbine

The power coefficient C_p is a nonlinear function of the blade pitch angle β and the tip-speed ratio by λ as given by,

$$\lambda = \left(\frac{R\omega_m}{v}\right)$$

Where, ω_m - Angular speed of the turbine rotor, R-Radius of the turbine Blades

The power coefficient C_p can be expressed as,

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right)exp\left(\frac{-C_5}{\lambda_i}\right) + C_6\lambda$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

The torque of the wind turbine can be expressed as,

$$T = \frac{1}{2}C_t(\lambda,\beta)\rho A V^3$$

$$C_t(\lambda,\beta) = C_p(\lambda,\beta)/\lambda$$

The given figure shows that the various power curve of wind turbine with various speed

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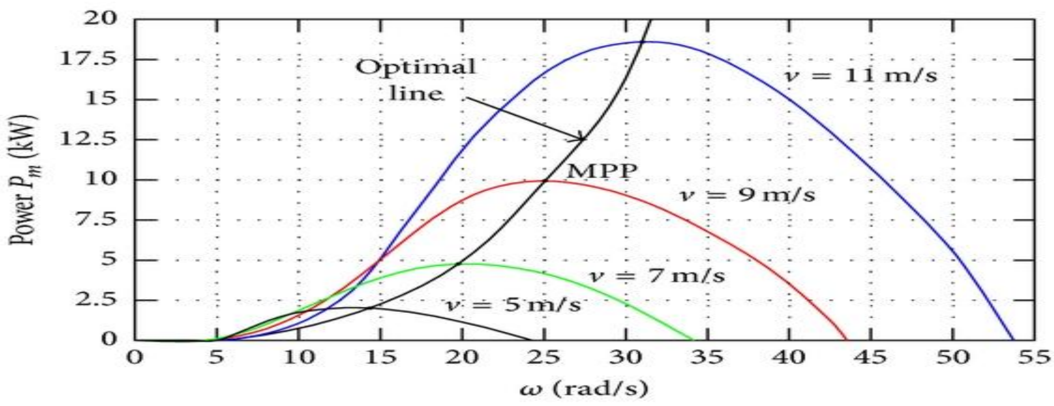

Fig.3 Characteristics of Wind Turbine

(C)Modeling of Permanent Magnet Synchronous Generator:- Before developing the mathematical model of the PMSM, several important assumptions need to be made: (1) the damping effect in the magnets and in the rotor are negligible; (2) the magnetic saturation effects are neglected; (3) the eddy current and hysteresis losses are neglected; (4) the back electromotive force (EMF) induced in the stator windings are sinusoidal; (5) for simplicity, all the equations of PMSMs are expressed in motor (consumer/load) notation, that is, negative current will be prevailing when the model refers to a generator. Negative current means that at the positive polarity of the terminal of a device the current is out of that terminal.

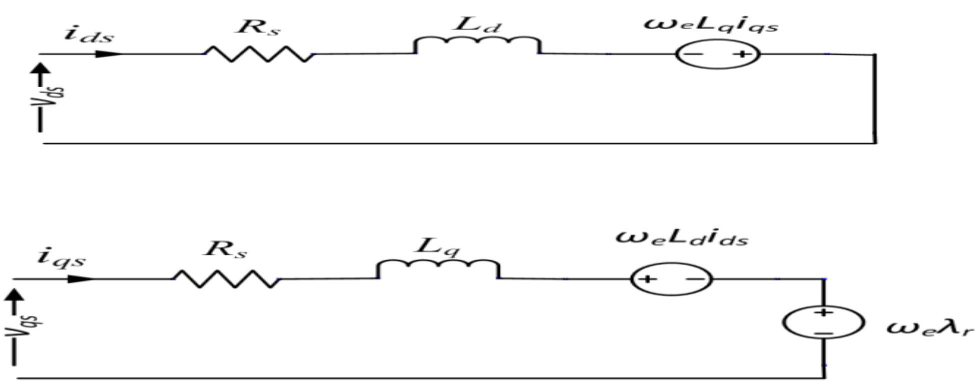

Fig. 4 Equivalent Circuit of PMSG in d-q reference frame

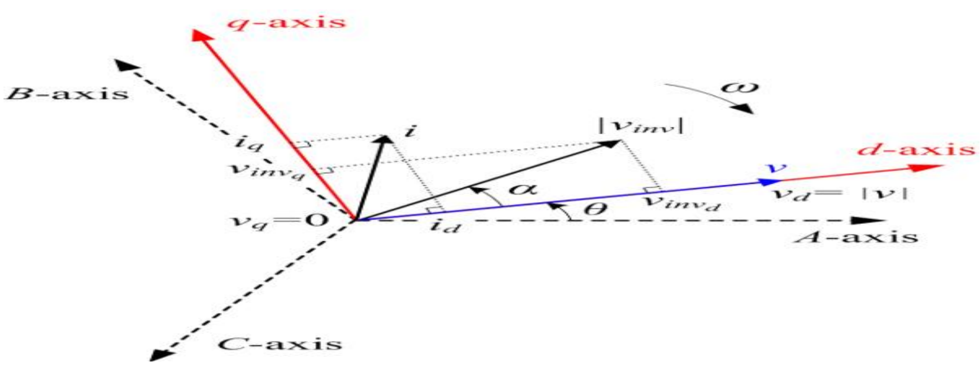

Fig.5.Vector Diagram

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V. CONTROL DIAGRAM

The control diagram of whole is based on two part-
1) Machine side control .
2) Grid side control.
In this diagram show the basic control of whole control structure of wind energy conversion system

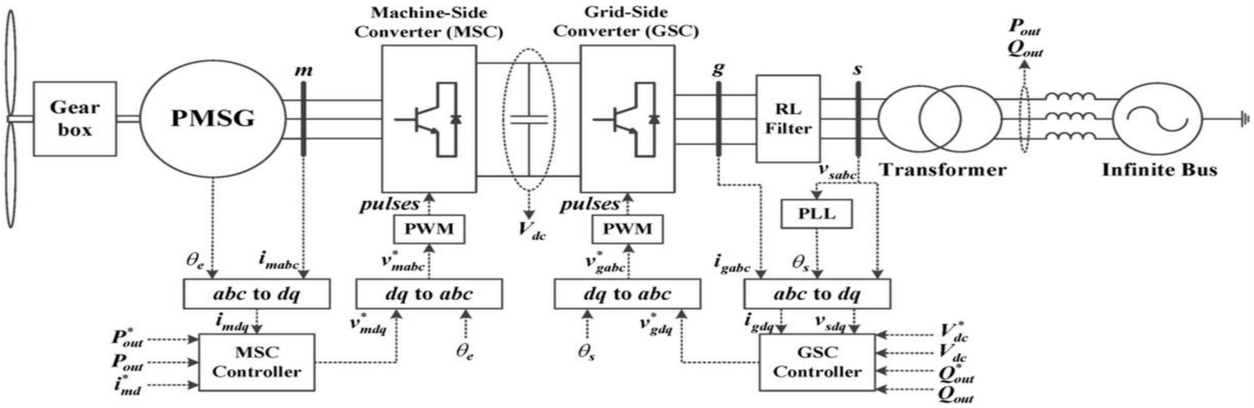
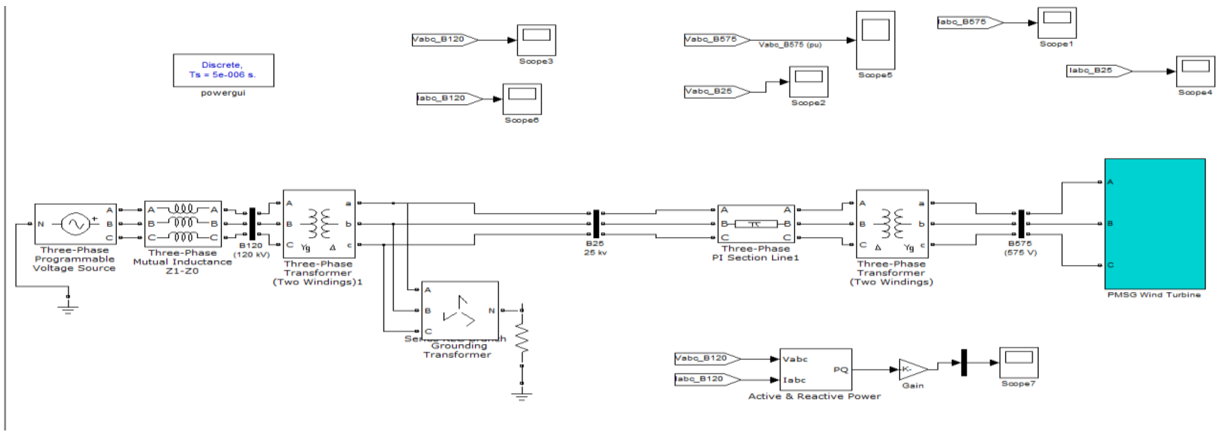


Fig.6 Control process of whole system

For the control of direct-drive PMSG systems, the information of rotor position and speed is needed to implement the advanced control algorithms such as the field oriented control (FOC) and direct torque control (DTC).

VI. SIMULATION

The given simulation model based on the principle is that a direct driven 10MW PMSG based wind turbine conversion system connected with grid



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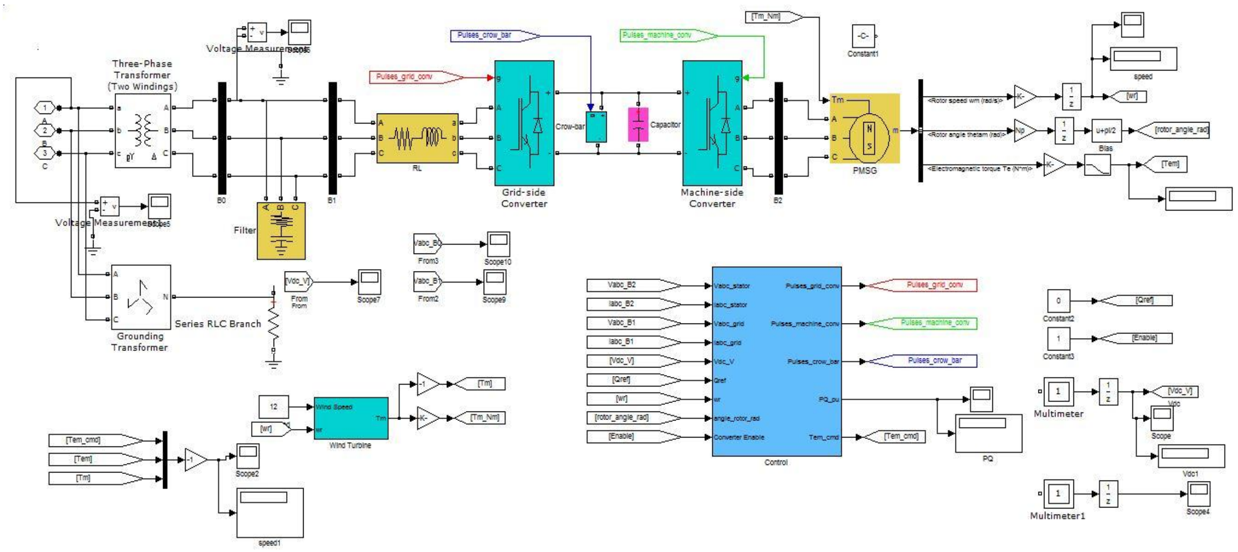
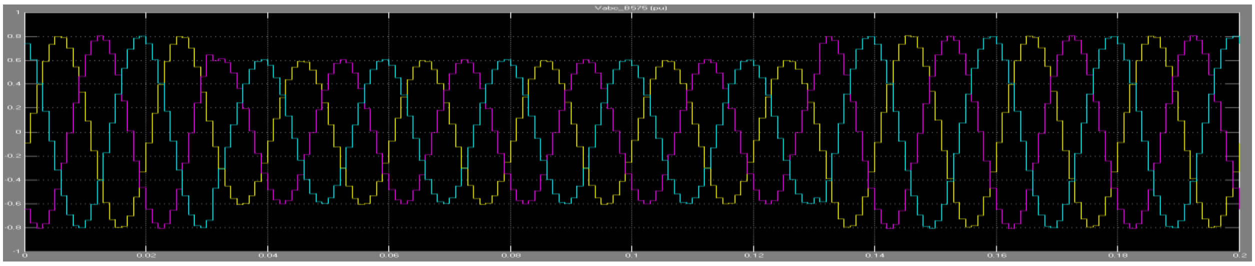


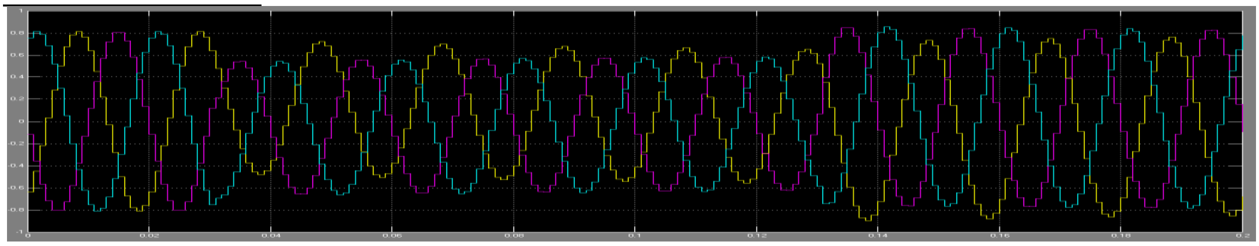
Fig.7. Simulation of wind energy conversion system in MAT LAB

VII. RESULT

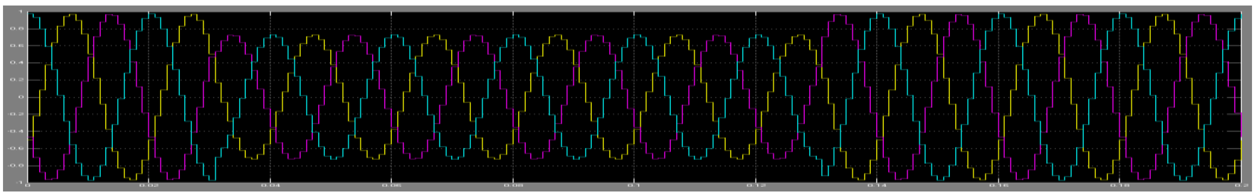
The given simulation Out-put result gives us voltage & current across B575V,B25KV & voltage across capacitor, voltage across V_dc, active & reactive power.



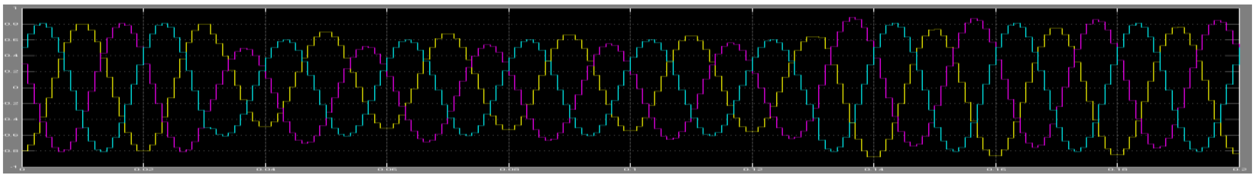
8.1 VOLTAGE ACROSS B575V



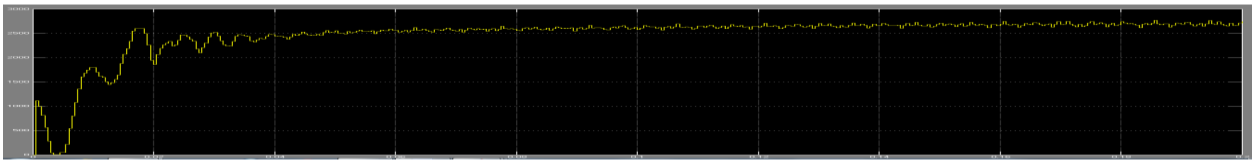
8.2. CURRENT ACROSS B575V



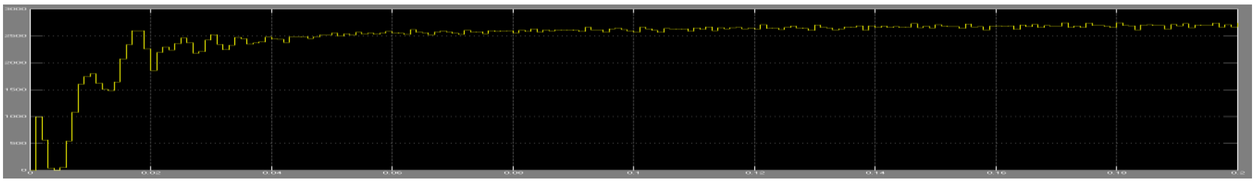
8.3. VOLTAGE ACROSS B25KV



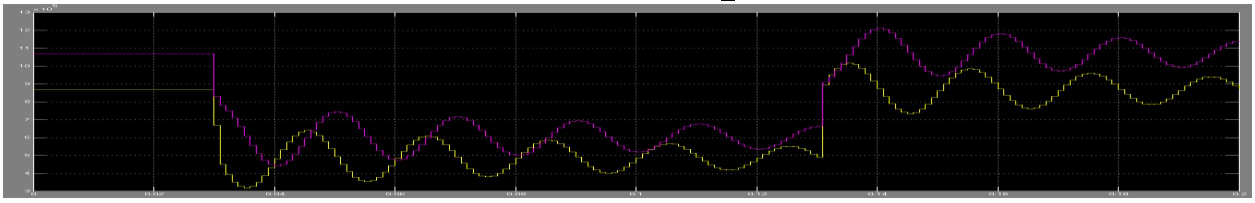
8.4. CURRENT ACROSS B25KV



8.5. VOLTAGE ACROSS CAPACITOR



8.6. VOLTAGE ACROSS V_dc



8.7 ACTIVE-REACTIVE POWER

VIII. CONCLUSION

This study analyzes the control strategies as well as models and designs and simulates the whole autonomous system of PMSG wind turbine feeding AC power to the utility grid in Matlab Simulink . The output result shows that a 10MW wind turbine connected to a 25kv distribution system exports power to a 120 kv grid through a 30 km, 25 kv feeder.

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BIOGRAPHY

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