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Active Power Control of Wind Farm Equipped DFIG Wind Turbines with Energy Storage System

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***Abstract:** Large wind turbine are subjected harmful loads that arise from spatially uneven and temporarly unsteady on coming Wind such loads are known sources of fatigue damage that reduce the turbine operational life time, ultimately increasing the Cost of wind energy to users. In recent years, a substantial amount of studies has been focused on active power of a wind turbine in a wind farm,so in order to control power we need configure the dfig wind turbine by rotor side control,grid side control pitchangle control by using these controllers along with configuration of energy storage system in a wind farm so on achieving active power simulation should be done by using above controllers on matlab simulink*
***Keyword:** doubly fed induction generator, energy storage system, wind farm control, pitch angle control, grid side controller, Rotor side controller, active power control.*

I. INTRODUCTION

Global concern about the environmental pollution and continuously increasing energy demand has led to the growing interest in innovative technologies for generation of clean and renewable electrical energy. Among a variety of renewable energy sources, wind power is the most rapidly growing one in the power industry the traditional wind turbine generator (WTG) systems employ squirrel-cage induction generators (SCIGs) to generate wind power. These WTGs have no speed control capability and cannot provide voltage or frequency support when connected to the power grid. During the past decade, the concept of a variable-speed wind turbine driving a doubly fed induction generator (DFIG) has received increasing attention because of its noticeable advantages over other WTG systems. Most existing wind farms and those in planning employ this type of WTGs. Compared to the fixed-speed SCIG wind turbines, the DFIG wind turbines can provide decoupled active and reactive power control of the generator, more efficient energy production, improved power quality and improved dynamic performance. All of those above-mentioned advantages of the DFIG are possible because of the control scheme that can be implemented in the back-to-back converters of the DFIG. Hence, the method of controlling this back-to-back converter plays a significant role in achieving better performance of the DFIG system. Different types of control schemes for the DFIG system can be found in the literatures which are discussed here. The Doubly Fed Induction Machine using an ac/dc/ac converter in the rotor circuit has long been a standard drive option for high power applications involving a limited speed range. the power converters only need to handle the rotor side power. In 1980, Leonhard explains the vector control technique used for the independent control of torque and excitation current. the converter design and control technique are well explained in. Pena, Clare and Asher gave a detailed design of the DFIG using back-to-back PWM voltage source converters in the rotor circuit and they also validated the system experimentally considering a grid connected system energy extraction from a DFIG wind turbine depends not only on the induction generator but also on the control strategies developed using different orientation frames. The DFIG usually operates in vector control mode based on the PI controllers in a synchronous reference frame either to the stator-flux-oriented (SFO) or stator-voltage-oriented (SVO) frames. The performance of DFIG wind power extraction is similar to using both SVO and SFO frames. But, it is found that a conventional wind power extraction approach using the SFO frame could deteriorate the power quality of the DFIG system while it is more stable to estimate the position of the stator-flux space vector by simply adding -90 degree to the stator-voltage space vector the variable-speed, variable-pitch wind turbine is designed to operate in maximum power point operation mode at low and medium wind speeds and in pitch control mode at higher wind speed. The vector control technique using SVO reference frame is used to get de-coupled control of active and reactive power from the DFIG based wind turbine. design for Rotor Side Converter and Grid Side Converter is presented clearly here by using control of Rotor side control, Grid side control, blade pitch the power of DFIG wind turbine can be equipped with wind farm supervisory control then the power can be a active power. In other words, wind turbines have to contribute not only to active power generation but also to the reactive power. Hence, wind turbines should have extended reactive power capability not only during voltage dips but also in steady state operation

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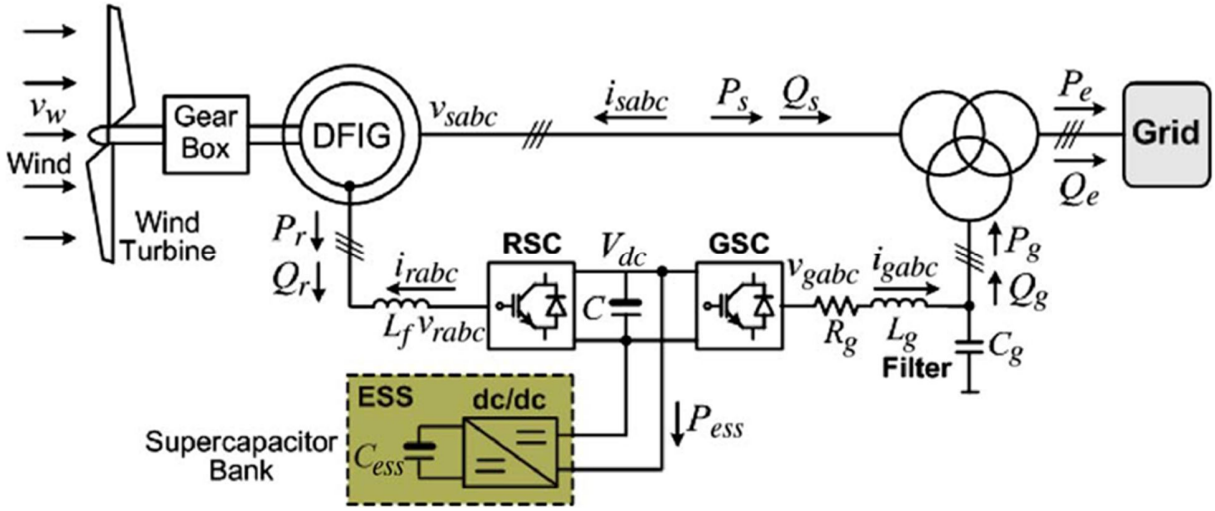


Fig.1. Energy storage system of a typical DFIG system

II. CONFIGURATION OF ENERGY STORAGE SYSTEM

Fig. 1 shows Energy storage systems (ESSs) of a typical DFIG have a function of converting electrical energy from a power system network form that can be stored for converting back to electrical energy.ESS has numerous applications including portable devices, smart grid, building integration, energy efficiency, transport vehicles, and stationary renewable energy resources , only three different distributed ESSs for renewable generation systems were introduced as battery, super capacitor, and electrical dual layer capacitor consists of an energy source bank, an inductance and a two-quadrant DC/DC converter connected to the DC link. It also describes how the controller of the DC/DC buck-boost mode generates the gate signals for gate 1 and gate 2.

$$C_{\text{ess}} = \frac{2P_n T}{V_{\text{SC}}^2}$$

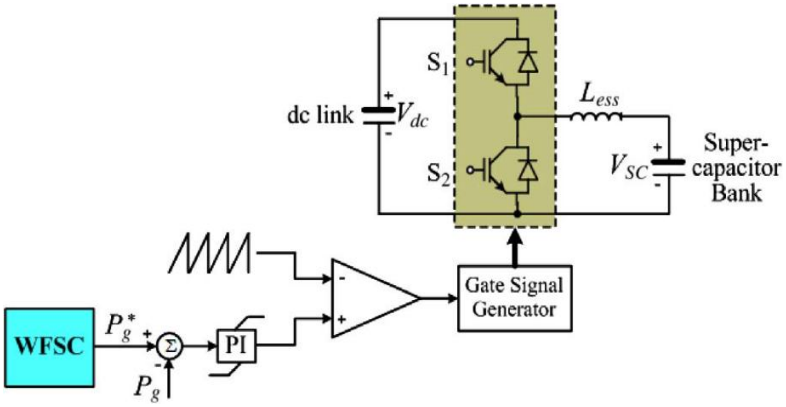


Fig. 2 control scheme of the ESS.

Fig 2 shows system uses DC-DC converters with controller of the. active power of DFIGs in the rotor side (Pr) or stator side (Ps) is greater than active power of DFIG and PMSG on the grid side (Pg), the ESS charges the energy flow from the DC bus to the ESS Bank through the S1 switch and S2 diode Therefore, the source of ESS works to absorb active power from the DC voltage, while acts as a step-down converter when boosts. The DC-DC converter design used as a buck converter circuit, and then of S1 in the buck mode When Pg is bigger than Pr, the E-ES energy discharges through S1 and S2, and energy flows to the DC bus (Vdc). In this case, the converter acts as a boost. The ESS bank serves as a source to supply active power, which results in the decrease of the voltage of S2 in the boost mode.

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III. CONTROL OF INDIVIDUAL DFIG WIND TURBINE

A. Control of the Rotor side controller

The main purpose of controlling rotor side converter is to control stator side active and reactive power independently. In order to implement the decoupled control method of active and reactive power, stator flux-oriented vector control scheme I adopted Stator voltage drop across resistance has been neglected as the stator resistance value are quite low in value. The DFIG is connected to stiff grid i.e. the frequency and amplitude of stator and grid voltage is assumed to be constant

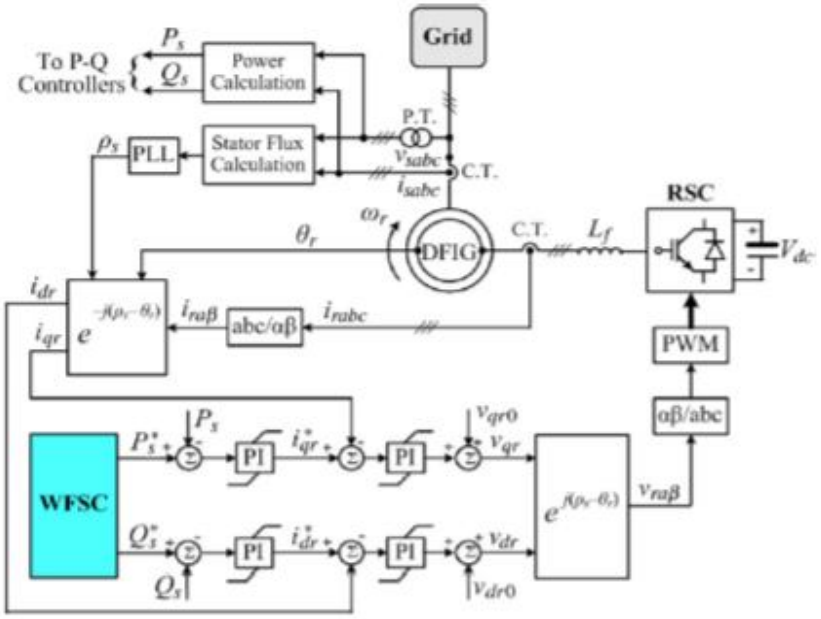


Fig. 3. control scheme of the RSC

The RSC control scheme consists of two cascaded vector control structure with inner current control loops which regulates independently the d-axis and q-axis rotor currents, i.e. dr I and qr I, according to some synchronously rotating reference frame. The outer control loop regulates the stator active power and reactive power independently. The stator voltage orientation (SVO) control principle for a DFIG is described in the q-axis of the rotating reference frame is aligned to the stator voltage V = 0 and qs V = s V. From the stator side flux. In this study, the q-axis flux is regulated to zero for the de-coupled control of active and reactive power the q- axis is rotating 90o ahead of d-axis at synchronous speed in the direction of rotation the stator flux vector is aligned with the d-axis of the stator.

The above assumption in mathematical form will be as follows.

$$Vds = 0; Vqs = Vs$$

$$\phi ds = \phi s : \phi qs = 0$$

This will reduce the active and reactive power to the following form.

$$Ps = 3/2\ (Vqs * iqs)$$

$$Qs = 3/2\ (Vqs * ids)$$

B. Control of Grid side controller

Grid side converter control is used to regulate the voltage across the DC link and sometime also to compensate harmonics. This is a two-stage controller scheme which is achieved by grid voltage-oriented vector control scheme i.e. by aligning the dq- axis in the direction of grid voltage. The detailed discussion on this grid converter control scheme is proposed It can produce constant amplitude and frequency at stator even if the wind speed is varying variable speed constant frequency operation

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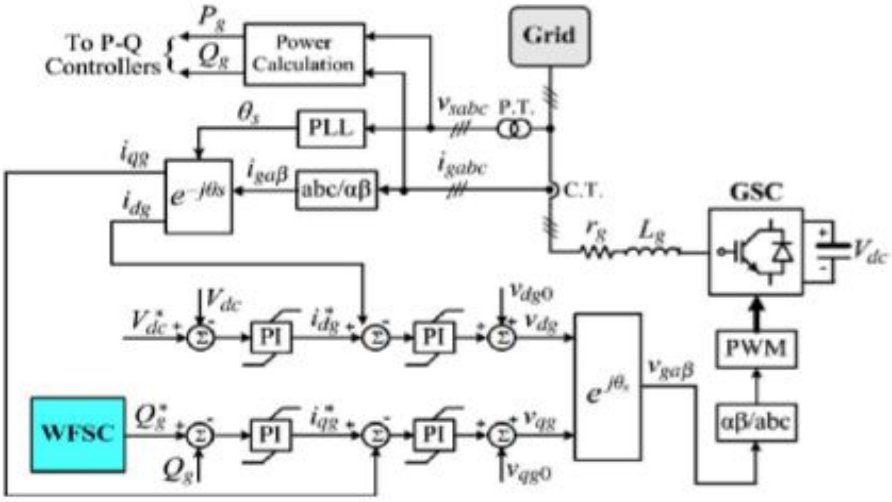


Fig .4 control scheme of GSC

To control the grid side converter, we adopt the grid side voltage-oriented vector control scheme. In this scheme. The rotating reference frame dq-axis will be rotated along the grid voltage. So Vdg will be equal to full grid voltage (Vdg= Vg) and Vqg will become 0. This will
reduce the power equation into the following form.

Pg= 3/2 (Vdg*idg); Qg= -3/2 (Vdg*iqg);

Dc link voltage control loop is developed on the principle of power balance on both side of GSC i.e. DC-link side and grid side. So in mathematical from it can be written as:

Vdc idc = Vdg i dg + Vqg iqg

As the d-axis of the reference frame is oriented towards the grid voltage, so Vqg component will be zero. Hence the above equation will reduce to

Vdc idc =Vdg idg

C. Pitch Angle Control scheme

The wind turbine blade pitch angle is controlled to regulate the output power from the wind turbine to match the load power demand and the power required to charge the embedded battery storage system. If the wind speed is high while the network load is small, pitch angle control is applied to reduce the output power from the DFIG so as to prevent the battery from being over-charged.
For electromagnetic transients in power systems the pitch control is of less interest the wind speed is less than rotational speed by point D

where ωr and Pe (= Ps + Pg)

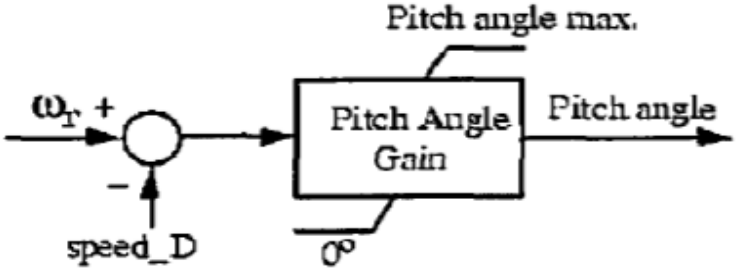


Fig 5 pitch angle control

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The lift and drag are dependent on the aerofoil of the blade and pitch angle of the blades θ. These forces can be expressed as an in-plane force, that causes the blade to rotate, and an out-of-plane force, that induces the nacelle and tower fore-aft motions. As the rotor spins, the rotational energy of the rotor is then transmitted via the drive trains to the generator, where the energy is converted into the electrical form. Notice that the in-plane and out-of-plane forces on the blade can be manipulated by the blade pitch angle. As a result, the rotational speed of the rotor and the motions of the blade and tower can be controlled by changing the blade pitch angles.so the active power is controlled by windfarm

IV. WIND FARM CONTROL

The Wind Farm Supervisory controller (WFSC) model that is a two-dimensional (2D) medium-fidelity wind farm model based on t equations that is developed for control purposes of power in a wind turbine design of a wind farm supervisory control algorithm requires a model of the wind farm system. The control objectives include requirements on the behaviour of the wind farm, as observed at the point of common coupling (PCC) between the wind farm and the onshore AC transmission grid. The model of the wind farm system should then encompass the wind turbines, the collection grid and the transmission to shore. The global inputs to the system are, primarily, the wind field, and voltage waveforms at the PCC and, secondarily, ocean waves. The global outputs are the active and reactive power – or equivalently, the current waveforms – at the point of common coupling with the onshore grid.

Control system design is usually conducted using highly simplified models of the system dynamics. This is appropriate, as only certain primary features of the system are likely to impact stability and controllability, while secondary influences can be considered as disturbances. However, optimal control methods require development of a cost function, which may include the degradation of electrical and mechanical components under long-term operation. It should not be taken for granted that the degradation of various components can be accurately represented by the outputs which are available from a highly simplified model.

The governing equation for power extraction is stated below:

$$P=F.V \tag{1}$$

The power losses of the wind turbine

$$P_{ei,max} = P_{mi,max} - P_{Li} = P_{si,max} + P_{ri,max} \tag{2}$$

The active power P_s of stator can be written in a synchronous dq reference frame

$$Ps = \frac{3}{2}(vdsids + vqsiqs)$$

$$\approx \frac{3}{2}[\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_s (i^2_{ds} + i^2_{qs})] \tag{3}$$

The active power Pr of rotor can be written in a synchronous dr frame

$$Pr = \frac{3}{2}(v_{dr}i_{dr} + v_{qr}i_{qr})$$

$$\approx \frac{3}{2}[-s\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_r(i^2_{dr} + i^2_{qr})] \tag{4}$$

Respective voltages of d-axis, q-axis of wind turbine

$$s = (\omega_s - \omega_r)/\omega_s \tag{5}$$

ω_r is the rotor speed of DFIG wind turbine. Here speed 's' as follows

$$s = \frac{P_r - 3i^2_r r_r}{Ps - 3i^2_s r_s} \tag{6}$$

By neglecting stator, rotor copper loss $3i^2_s r_s$, $3i^2_r r_r$ of the DFIG, wind turbine power can be estimated as,

$$P_r = -sP_s. \tag{7}$$

The maximum mechanical power $P_{m,\,max}$, DFIG wind turbine as

$$P_{m,\,max} = \sum_{t=1}^{N} P_{mi,max} \tag{8}$$

Total active output power of rotor DFIG wind turbine as

$$P_{r\,max} = \sum_{t=1}^{N} P_{ei,max} \tag{9}$$

The active output power of a stator DFIG wind turbine as

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$$P_{s,max} = \sum_{t=1}^{N} P_{si,max} \quad (10)$$

The constant demand power P_d ,energy storage system of wind turbine

$$P_{ess,d} = P_{e,max} - P_d \quad (11)$$

Voltage of the energy storage system:

$$V_{i,\,min} < V_{essi} < V_{i,\,max} \quad (12)$$

The maximum and minimum voltages of energy storage systemof DFIG,

$$P_{essi,\,max} = \pm C_{ess} V_{ess} \left| \frac{dV_{essi}}{dt} \right|_{max} \quad (13)$$

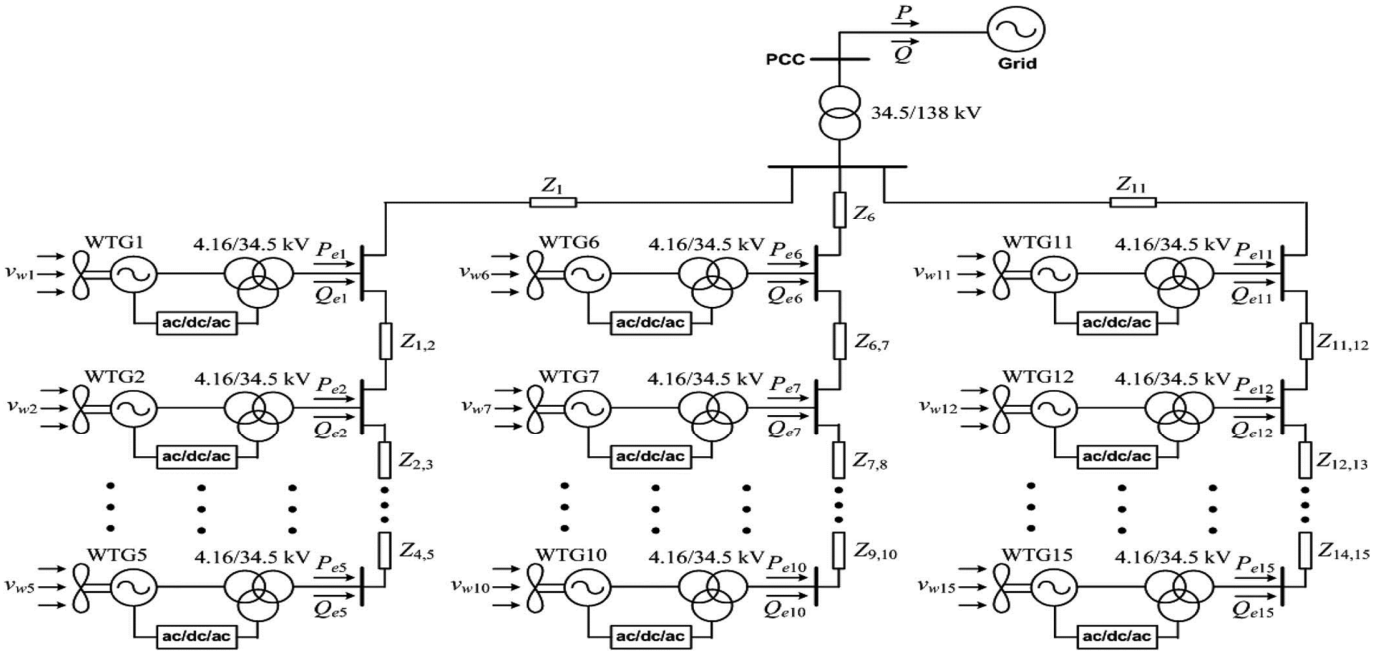


Fig. 6. A wind farm with DFIG wind turbines connected to grid

V. SIMULATION RESULTS

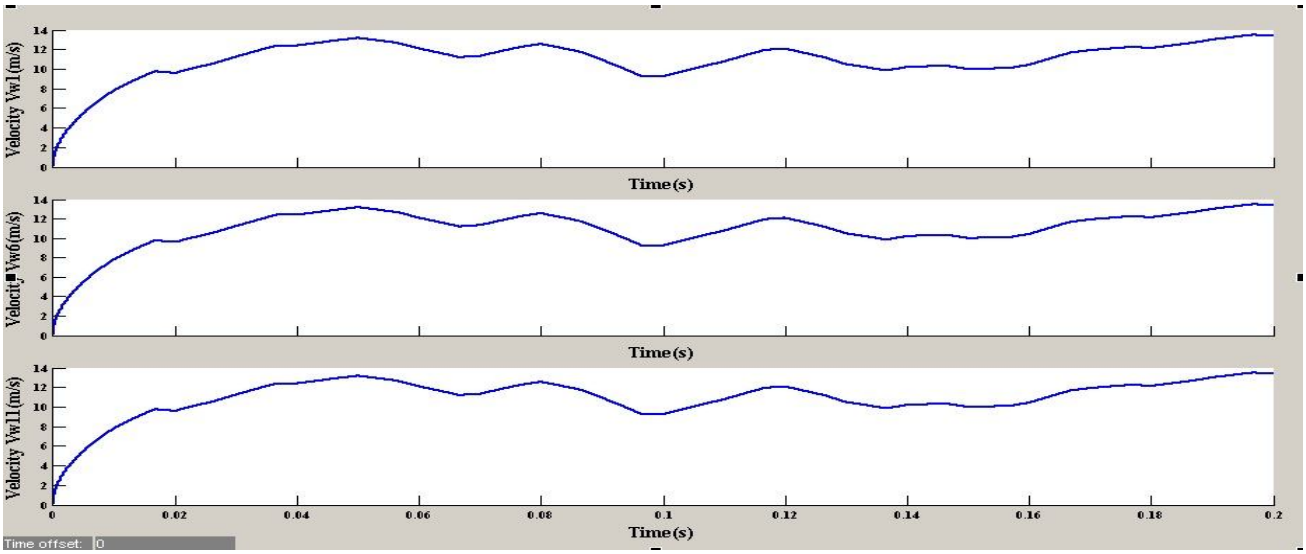


Fig.7. Shows the velocity of various wind turbines in the wind farm

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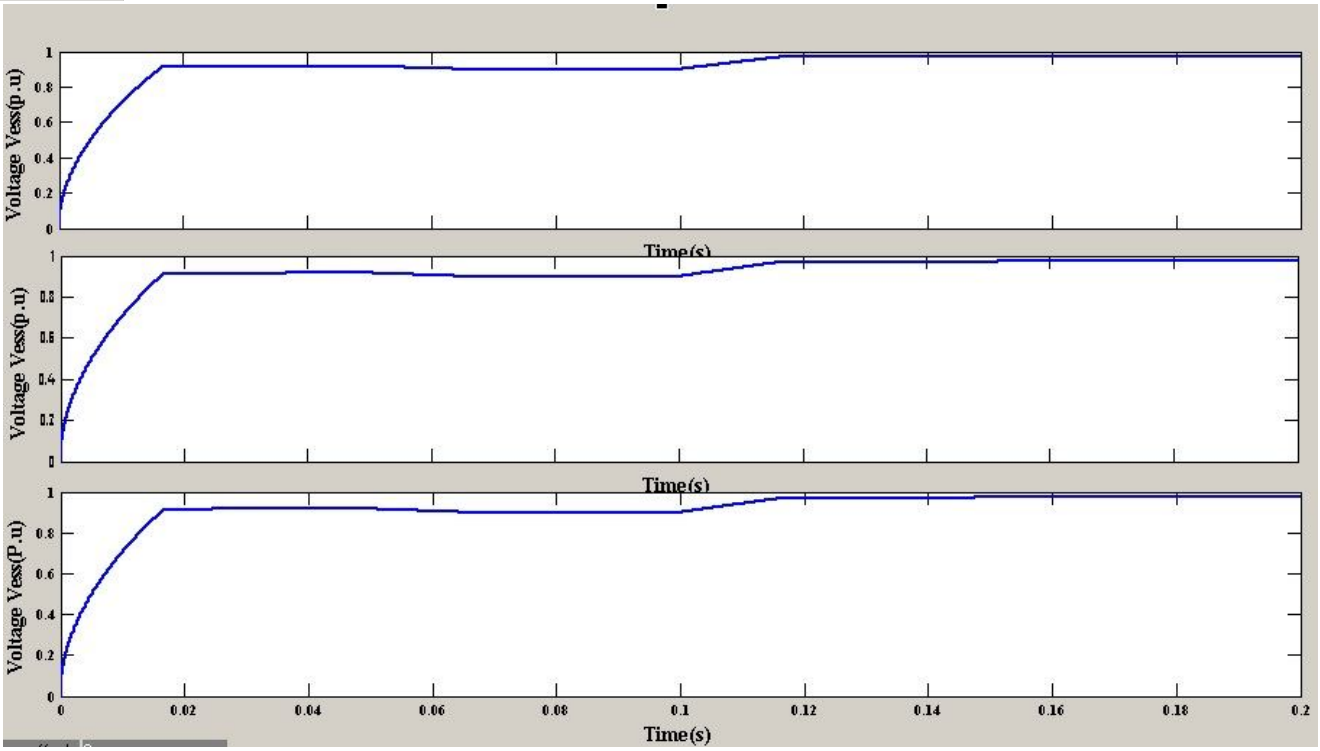


Fig.8.shows Voltages of wind turbines in wind farm

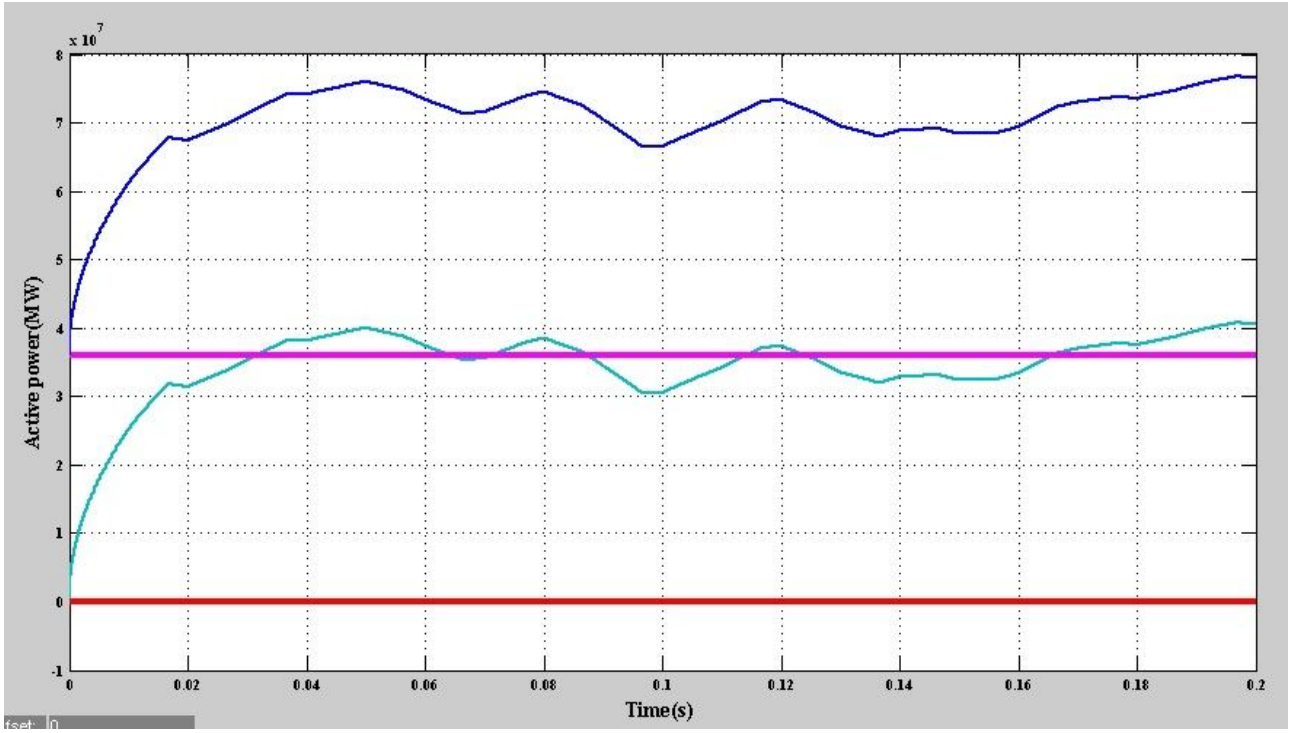


Fig.9.shows the generating active powers of wind turbines as we observe the figure the real power starts from initial power

Position starts at 0.5. Now when load increases suddenly on grid connected to wind farm power fluctuates here power can't controlled

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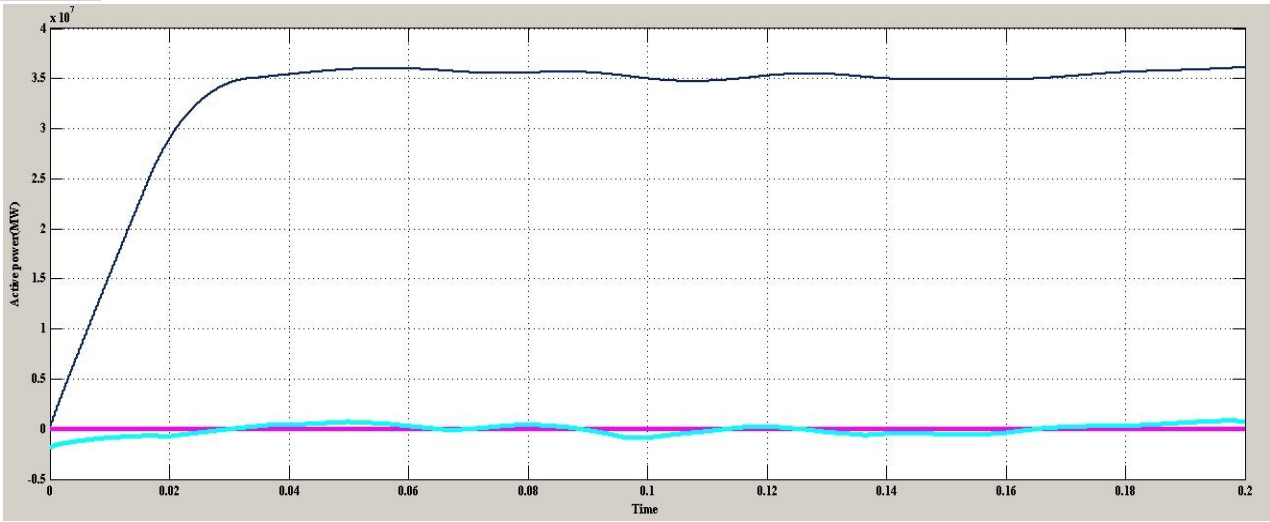


Fig.10.shows the active power outputs of wind farm here also power starts from initial 0.5position and vary from 0.5 to 3.5 at certain time it suddenly falls by decreasing the minimum load on wind turbine and it gains its original position because of some harmonics wind farm of power quality

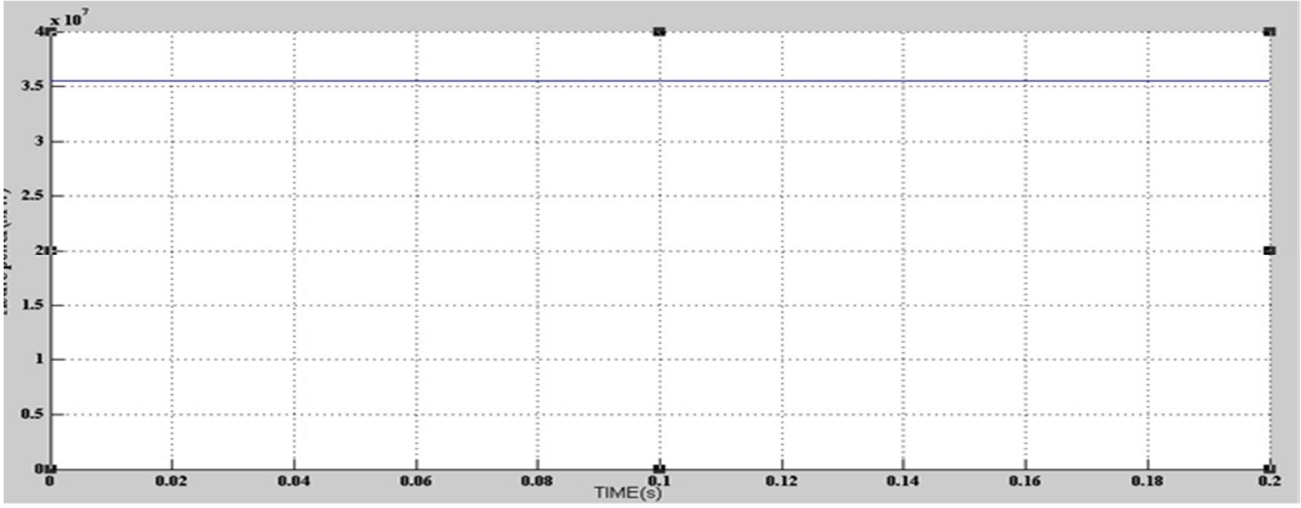


Fig.11.shows that active power is totally controlled in wind farm as we use the controllers such as RSC,GSC,angle pitch control Now there will be no losses found and also demand supply are in balance

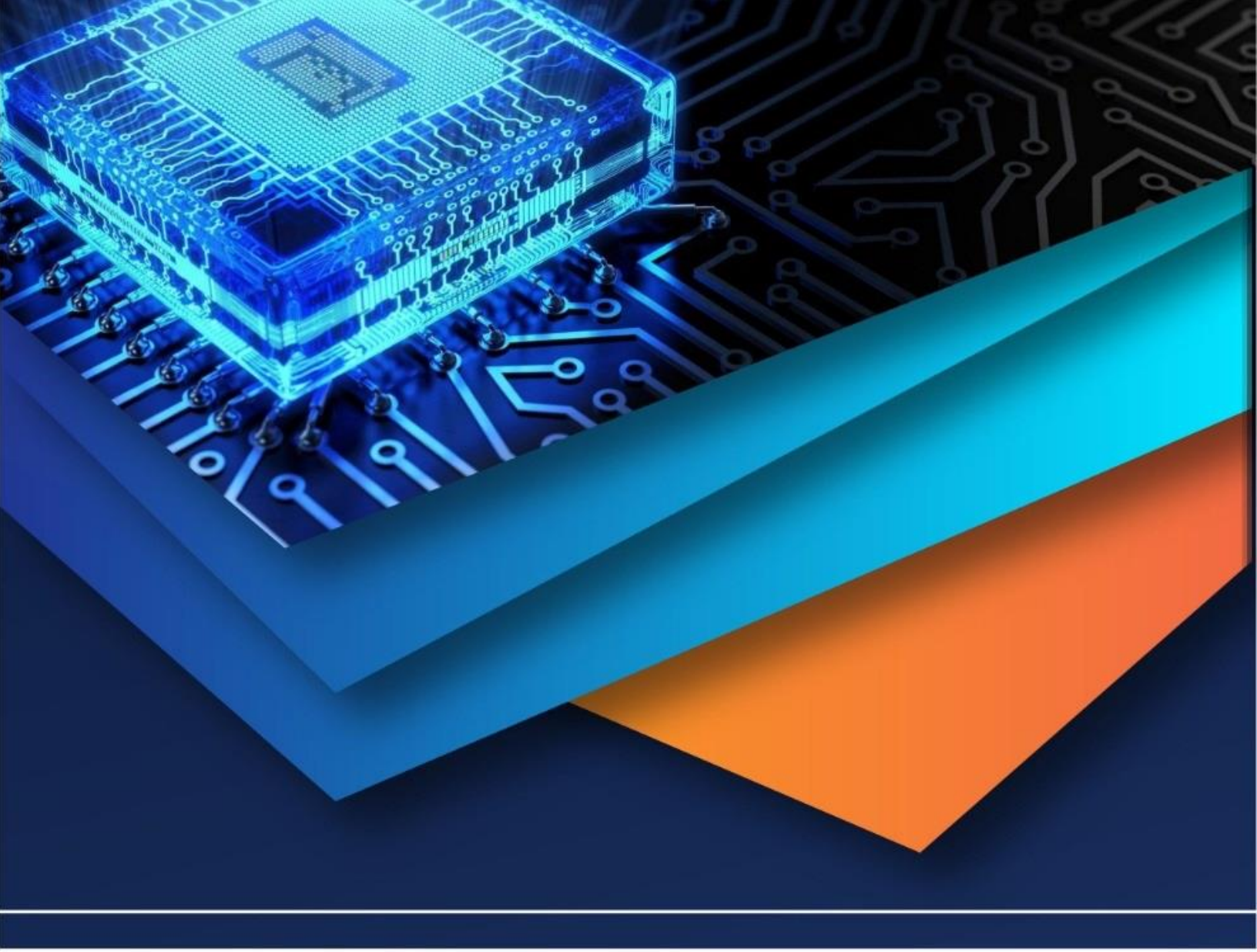
VI. CONCLUSION

In this paper by configuration of DFIG turbine by controlling RSC, GSC, Energy storage system, Pitch angle control in a wind farm, by minimizing all losses to achieve active power can be controlled in a wind farm to supply quality power to end users.

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