e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

ENHANCING THE WIND POWER SYSTEM'S PERFORMANCE WITH A FOCUS ON POWER QUALITY ISSUES

Anand Ghidole[*1], **Shailendra Kumar Bohidar**[*2]

[*1]M.Tech Research Scholar (Power Electronics), School Of Engineering & IT, MATS University, Raipur, C.G., India.

[*2]Associate Professor, School Of Engineering & IT, MATS University, Raipur, C.G., India.

ABSTRACT

Due to its clean and renewable nature, wind energy is becoming one of the important renewable sources of energy in the world. Through its collaboration with other renewable sources of energy, such as solar energy, the world energy crises can be solved in the future. Comparatively with the past and due to the progressive integration of the nonlinear loads in the grid, the principal role of a Wind Energy Conversion System (WECS) is not only to capture the maximum power from the wind, but also to improve the quality of power. Consequently, with the development of the wind farms which are integrated into the grid, power quality could be better improved in the future. In this work Variable speed wind generator are used which is more attractive than fixed speed systems because of their efficient energy production, improved power quality and dynamic performance during grid faults. Here we design simulation model of wind power plant using doubly fed induction generator with PI controller and pitch control system for mitigation of power quality issue. Results obtained by both system shows the output power (active and reactive) are free from harmonics and it is stable. The global transition towards sustainable energy sources has led to a significant increase in the integration of wind power into the electricity grid. While wind energy offers numerous environmental benefits, its intermittent nature and variability pose challenges to power quality within the grid. This abstract outline a comprehensive study aimed at enhancing the performance of wind power systems with a specific emphasis on addressing power quality issues. The research investigates the impact of wind power integration on the grid's power quality parameters, including voltage stability, frequency regulation, and harmonics. A detailed analysis of the existing power quality standards and regulations is conducted to identify gaps and potential areas for improvement. The study explores advanced control strategies, grid integration techniques, and energy storage solutions to mitigate power quality concerns associated with wind power fluctuations. Furthermore, the research delves into the development and implementation of intelligent monitoring and control systems to enhance the predictability and reliability of wind power generation. Advanced sensor technologies and machine learning algorithms are employed to predict wind power variations and optimize the performance of grid-connected wind farms. The integration of energy storage systems and smart grid technologies is explored to buffer the effects of intermittent wind power generation and enhance overall grid stability. The findings of this study contribute valuable insights into the effective integration of wind power systems while maintaining high power quality standards. The proposed enhancements not only address the challenges posed by the variable nature of wind energy but also pave the way for a more resilient and sustainable energy infrastructure. The research outcomes are expected to guide future developments in wind power technology, facilitating a seamless transition towards a cleaner and more reliable energy landscape

Keywords: Wind Power, Power Systems, Environment, Renewable, Power Factor.

I. INTRODUCTION

An excellent clean, renewable, and cost-free energy source for generating electricity is wind power. Because of variations in air pressure, the earth's atmospheric air mass creates air flow. The variations in solar heating across the surface of the earth cause this variation in air pressure

The primary drivers of the ongoing increase in energy demand are the planet's population growth and rising living standards. The majority of countries are seeing a decline in the amount of energy used per GDP, but because GDP is growing faster than efficiency, more resources are being used to produce energy. It is predicted that in the next decades, this trend will continue. Due to the scarcity of fossil fuels like coal, natural gas, oil, and nuclear power, it is imperative to employ renewable energy sources to generate electricity. Additionally, using fossil fuels increases greenhouse gas emissions, and using nuclear energy increases the risk of radiation product leakage. It is widely acknowledged that the world's fossil fuel supplies are finite and that the cost of producing gas, coal, and oil has risen steadily since its peak. Since fossil fuels are limited resources, they will eventually run out entirely. In contrast to the aforementioned example, the lack of emissions of harmful gases like carbon dioxide and sulphur dioxide has led to a significant demand for renewable energies.

Water, wind, solar, and biomass energy are among the different forms of renewable energy sources that are contributing to the current energy demand. However, the main disadvantage of hydroelectric power plants is that they are expensive to construct and require a long operating period before they start to turn a profit. Building dams may even cause land to flood, wreaking havoc on the environment. Similarly, solar thermal collectors can only be used to extract solar energy when there is sunlight present. Because of this, installing solar energy equipment becomes unfeasible in regions with low sunlight or significant rainfall. The main factors contributing to wind energy's popularity are its low operating costs, increased efficiency, and non-polluting nature. As wind energy continues to grow, numerous new modelling and enhanced simulation techniques have been developed. The process of harnessing wind power has long been a challenge. Grain grinding and water pumping have long been done with wind mills. Since then, numerous new technologies have been tested and proposed, including pitch control and variable speed control techniques. There is no grid because wind turbines can operate in an isolating mode at times. A wind turbine typically has two, three, or even more than three blades. Nonetheless, a wind turbine should have no more than three blades, according to the principle of aerodynamics. The primary generators used in wind turbines are synchronous and asynchronous ac machines.

The problem has led to a great deal of research and development into renewable energy, which includes solar energy, wind energy, geothermal energy, and other forms of energy. The benefits of renewable energy include its abundance, cleanliness, and growing affordability. Actually, compared to the annual production of 70 million metric tonnes of carbon emissions from fossil fuels, renewable energy sources contribute to this reduction. Electricity, as we all know, has made human life simpler and easier. Since we couldn't imagine living without it, electricity is one of the most fundamental aspects of our existence. We utilise electricity for a variety of purposes, including residential, commercial, and agricultural ones. We also know that there is a serious threat to the world.Wind energy is the kinetic energy which is related to the movement of atmospheric air. Wind energy is used from thousands of years for sailing, grinding grains and for irrigation purposes. In this energy conversion system wind turbine is used for the conversion of wind power into electrical power. Electrical generator which is placed inside the turbine converts the mechanical power into electric power. The production of energy from wind turbine depends on the velocity of wind acting on wind turbine.

1.1 RENEWABLE ENERGY SOURCES

Renewable energy sources (RES) are currently producing a rapidly increasing percentage of the world's electricity, which is not surprising given that electricity is one of the most sought-after commodities for human use. When the fuels in these conventional energy sources are burned, greenhouse gases are released. Renewable energy has gained popularity as a popular substitute for traditional methods of producing electricity to meet needs and requirements since the current oil crisis. The trend in the production of electrical power today indicates a move away from the majority of traditional sources, like fossil fuel-based energy, and towards renewable energy sources, like solar, wind, and water energy. Renewable energy sources come in a variety of forms, including solar energy, wood and wood waste, wind energy, hydro

1.2 WIND ENERGY

We needed another renewable energy source to generate the most power possible because, as we all know, solar energy is insufficient during overcast days, the rainy season, and most nights. Among these is wind energy, which is particularly well-liked during the wet or cloudy season and primarily at night when the solar system is not operating at its best. When it comes to wind energy, we use turbines to convert mechanical power into electric power. This method has several benefits, including no water consumption, no pollution, and no other negative effects. Here, the only difficulties are that the wind doesn't always blow at a steady speed.

1.3 WIND ENERGY CONVERSION SYSTEM STRUCTURE

It is commonly known that the production of electricity from wind energy is socially, environmentally, and economically competitive in all of its applications. One of the renewable energy sources that is expanding the fastest in the world for power supply is wind power. One significant step forward is the development of the mechatronics system. Developing at stable for the wind turbine system is essential because the power converter's design is heavily reliant on the turbine's characteristics. The generator, gearbox, and wind turbine make up the dynamic portion of the wind turbine system. Refinement of the electrical part design is not practical because the wind turbine's dynamic characteristic depends on the operating environment, which is typically tested in a wind tunnel.

1.4 FIXED SPEED WECS WITHOUT POWER CONVERTERS

In Figure 1, the structure of a fixed speed WECS without power electronic interface converter is shown in which the gear box is used to match the speed of wind turbine and generator for delivering the rated power at rated speed. During the system start-up, heavy in-rush current is limited using a soft starter and later it is bypassed by a switch. For compensating the reactive power drawn by the induction generator, a three phase capacitor bank is installed.

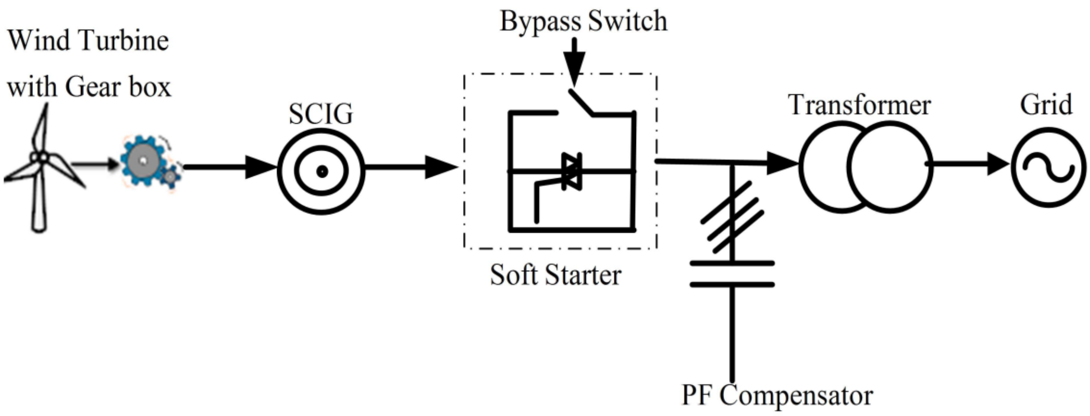

Figure 1: Fixed speed WECS without power converters interface

1.5 VARIABLE SPEED WECS

Variable speed WECS systems are classified into two types based on the power rating of thepower electronics converter, such as reduced capacity converters and full capacity converters.Due to the use of these power converters, decoupling between the generator and grid can bemade automatically.

Fig. 2 and Fig. 3 shows the reduced capacity converters of WECS where as Fig. 1.4 depicts the structure of the full capacity converter WECS. Variable speed reduced capacityconverters are designed only with wound rotor induction generators, since rotor currents canbe controlled on rotor side for variable speed operation without the need for total powerin power system.

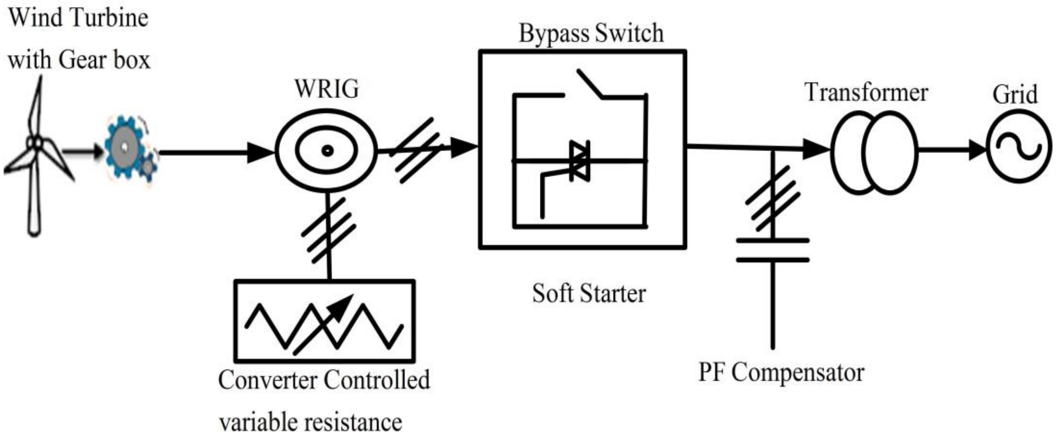

Figure 2: Variable speed WECS with variable rotor resistance

Reduced capacity converters are again classified into two types such as wound rotor induction generator with variable rotor resistance shown in Fig.1.2 and doubly fed induction generator (DFIG) with rotor converter shown in Fig. 1.3. Wound rotor induction generators is shown in Fig. 1.2, with a variable resistance in the rotorcircuit. Variable speed operation of the turbine is achieved by varying the rotor resistancewhich affects the torque/speed characteristics of generator. The rotor resistance is varied with the help of power converter.

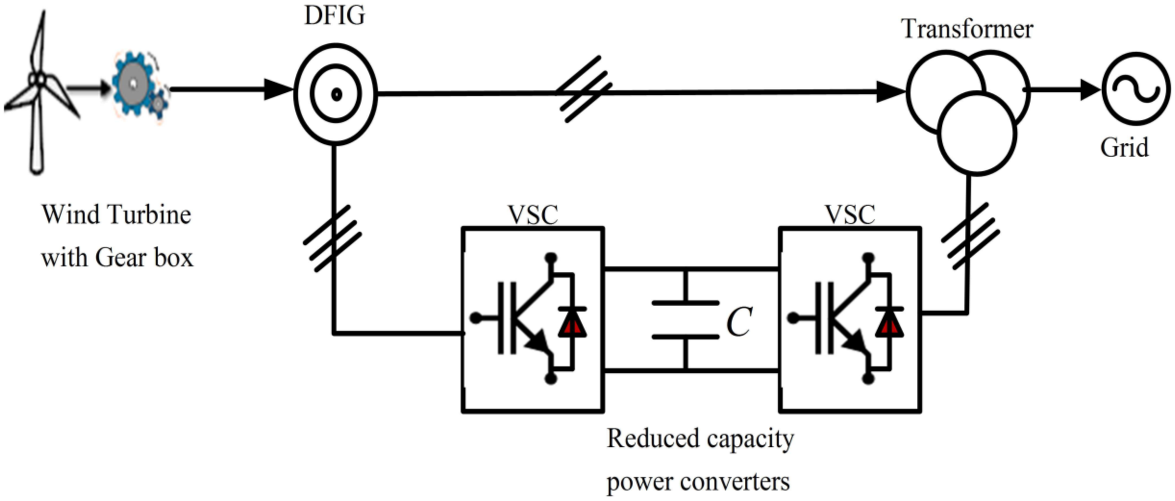

Figure 3: Variable speed WECS with reduced power capacity converters

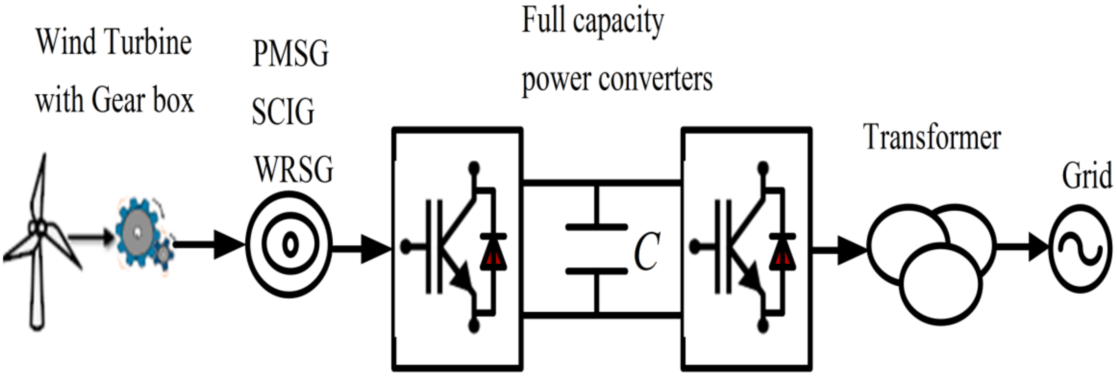

Figure 4: Variable speed WECS with full capacity converters

1.6 REVIEW OF CONTROL TECHNIQUES FOR WECS

A number of controllers are proposed in the literature for DFIG WECS to extract maximum power from WECS.

- **MPPT ALGORITHMS**

Conventional hill climb searching (HCS) has been proposed in [3] for maximum power point tracking (MPPT) for WECS. But these MPPT algorithms are not effective for tracking the maximum power reference.

- **FLUX ORIENTED CONTROL (FOC)**

There are three types of field oriented control: rotor, air gap, and stator flux orientations [19]. Indirect field oriented control (IFOC) and direct field oriented control (DFOC) are two more classifications for FOC. While IFOC is based on calculated slip frequency and measured stator speed, FOC is implemented based on stator voltage and current measurements. Additional benefits include more accurate flux estimation and direct control over stator voltage in the field weakening region when the stator flux is oriented instead of the rotor flux. As illustrated in Fig. 1.5, stator flux is estimated from phase currents and terminal voltages using the d−q or α-β reference frame.

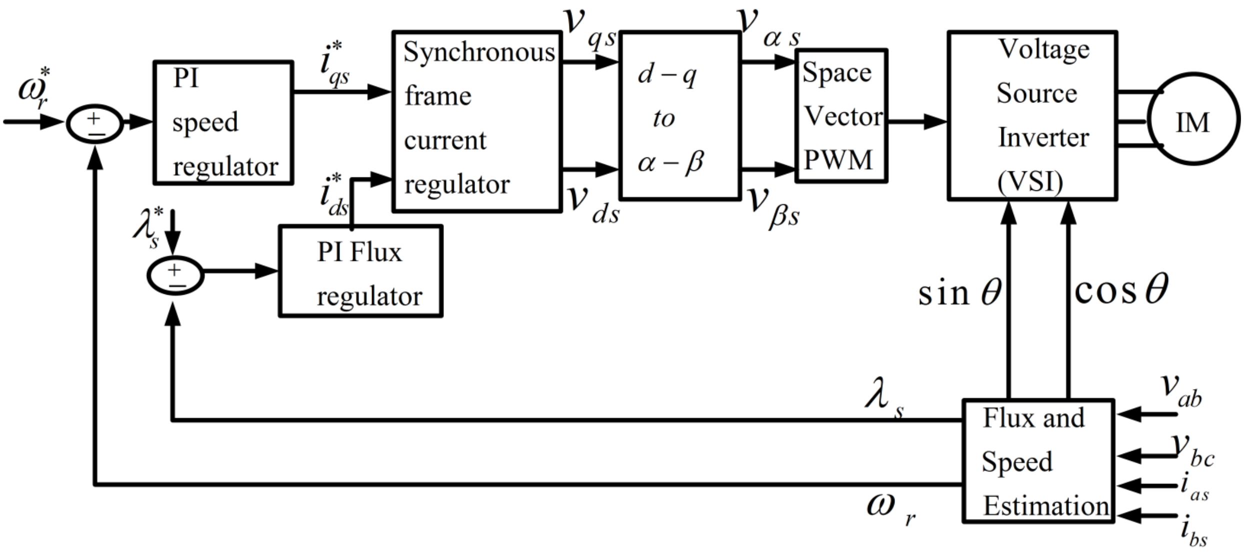

Figure 5: Schematic diagram of Flux Oriented Control

1.7 STATOR VOLTAGE ORIENTED CONTROL (SVOC)

Since decoupling between torque and flux can be achieved in the vector control method and in comparison to flux control, SVOC is favoured over FOC. Reactive power production is limited in stator field-oriented control (FOC) when the machine reaches an unstable position. As a result, SVOC is built with an inner rotor control loop that precisely tracks its reference values through PI controller tuning that ensures stability. The DFIG's current dynamics outpace the wind turbine's mechanical dynamics. The d-axis in the SVOC scheme [23] is aligned with the stator voltage reference frame. Grid voltage angle must be measured and its angle must be detected for the voltage orientation in order to realise SVOC.

1.8 DIRECT TORQUE CONTROL (DTC)

To overcome the tuning difficulties of the controllers in vector control (VC) scheme and to reduce the control complexity, a direct torque control (DTC)[24, 33] has been proposed . DTC is used to control the electromagnetic torque of the generator by adjusting its torque angle and maintaining the stator flux constant at rated value.

One of the problems associated with the DTC scheme is that its performance deteriorates during starting and very-low-speed operations. This is mainly due to repeated selection of zero voltage vectors at low speed resulting in flux level reduction owing to the stator resistance drop.

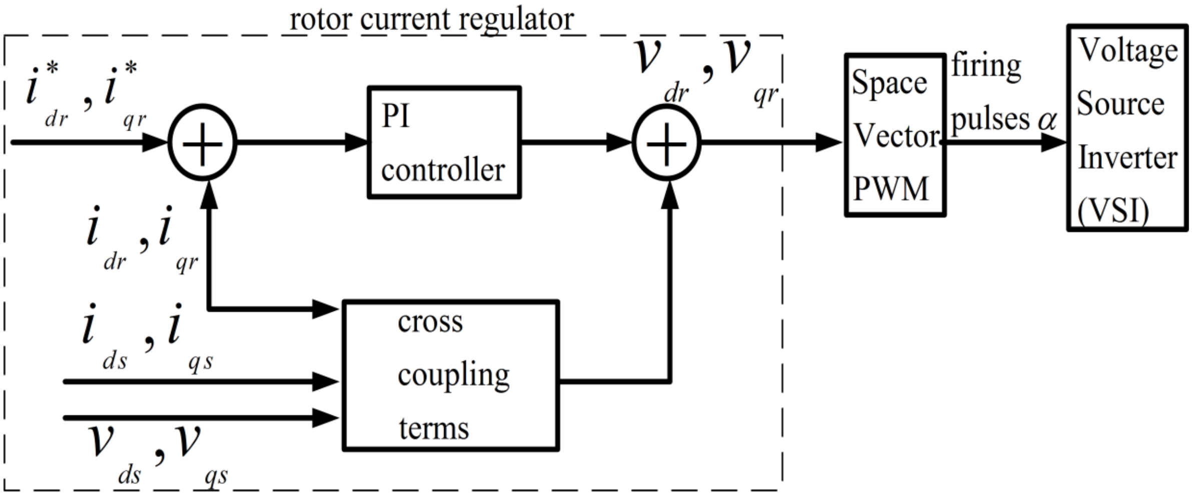

Figure 6: Schematic diagram of Rotor Current Controller

1.9 MOTIVATION

- Among the different renewable energy sources, wind power is the most dependable and rapidly developing. Wind turbines can run in two modes: fixed speed and variable speed.
- The generator is directly connected to the grid when operating at a fixed speed; when operating at a variable speed, power electronic equipment is used to control the generator. Consequently, the double fed induction generator, which can function both in standalone and grid mode, is essential.
- The variable speed, lower converter cost, fewer switching losses, increased energy efficiency, and enhanced power quality of DFIG have drawn increased attention. At first, a PI controller was the only tool used to implement the controller in the double fed induction generator.

1.10 PROBLEM STATEMENT

Electricity is one of the many necessities for modern life, along with water, energy, food, and other necessities. Without it, life would not function as it does. There are several ways to generate electricity, including renewable and non-renewable energy sources. Since we are aware that non-renewable energy sources will eventually run out, our primary goal is to concentrate on renewable energy sources in order to increase electricity production and meet human needs.

A characteristics curve that expressed the relationship between torque and power and rotor speed was coded for various wind speeds. Plotting was done to determine how much energy could be extracted and transformed into mechanically useful.

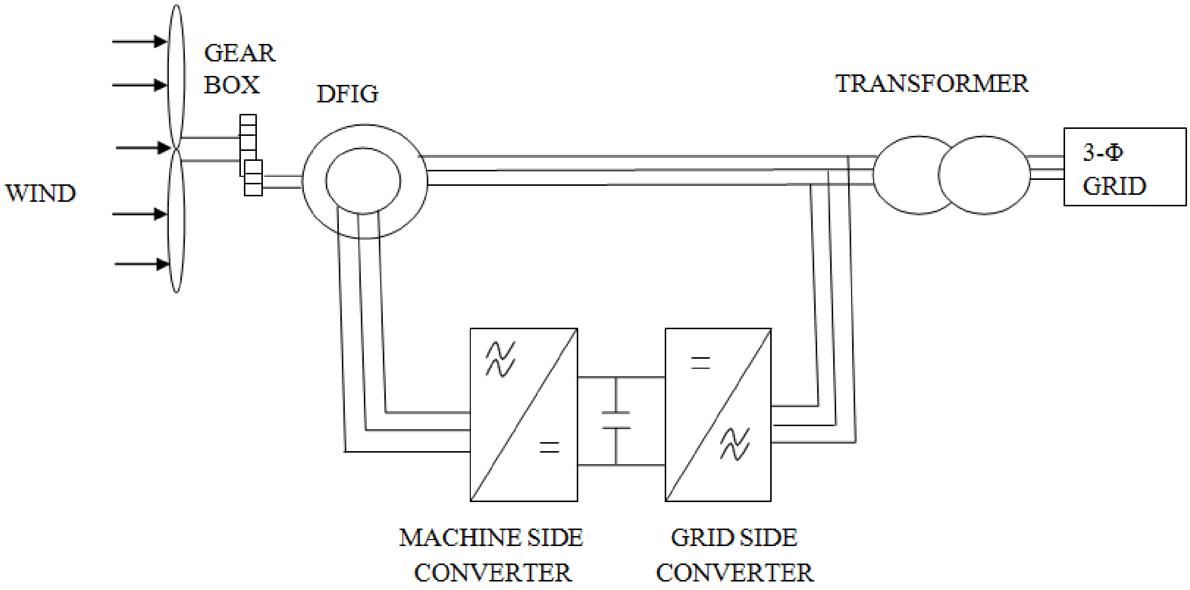

Figure 7: DFIG based wind energy conversion system

II. LITERATURE SURVEY

- In the literature review section a detailed study of DFIG, of grid side vector control technique using traditional PI has been studied from a doubly fed induction generator using back to back PWM converters and its application to variable speed wind energy generation. Numerous researchers have done extensive work to make the dc link capacitor voltage constant regardless of any occurrence of grid faults. New techniques have been approached so as to make the performance of the grid side even better. The bulk of chapters and published research paper relevant to this project considered for this research work. This chapter represents the review of previous studies and different methodology used in this field. To investigating the future research will be reviewed.
- Power electronics is making an important contribution in modern wind energy. Wind turbines equipped with power converters such as doubly-fed induction generator (DFIG) wind turbines and permanent magnet synchronous generator (PMSG) wind turbines, have increased the flexibility of turbine control. This gives

them the possibility to be inherently more grid-friendly than the conventional fixed-speed concepts and potentially increases market penetration.

- In the recent years, this technology has undergone a fast evolution due to the development of high switching frequency semiconductors and real-time computer controllers [1]. As a result, many advanced control techniques can be implemented to regulate mega-watt scale power. Component ratings are getting higher but the price per kVA is going down [2]. However, the power converter as a subassembly of the wind
- turbine is subject to high failure rates, which makes them a major concern in the overall reliability of future offshore wind farm developments [3]. Due to the limited accessibility of the offshore environment, the failure rates of wind turbine systems need to be minimized in order to improve the availability. As a result, the power converter becomes particularly crucial to improve the wind turbine performance.
- It is very common that reliability studies are based on field data. Due to the commercial sensitivity of wind turbine systems, the available data source pool used to study reliability of wind turbine technology often is restricted to a few databases [4], not all of which are publicly accessible.Some other publicly available failure statistics such as LWK, Wind stats, EPRI also contribute to reliability research. A brief introduction on each of these data sources is given in [5]. These surveys are based on wind turbines with different configurations and sizes (from 200kW to 2MW).
- PMSGs, are considered to be the most-promising technologies for future large offshore installations. A PMSG equipped with a back-to-back power converter seems to be very attractive for wind turbines larger than 3MW, which may become the dominant concept instead of the DFIG wind turbine [6].
- The wind generation system consists of wind turbine which gives the fluctuating output under normal operation due to variation in the wind. The induction generators that produce electricity on getting the mechanical input from the wind turbine absorb reactive power. The deficiency of the reactive power significantly affects the terminal voltage of the plant. The power quality issues like voltage sag, swell, flickers etc. occurs when wind plant is directly connected to the electricity grid [7].
- A controller parameter adjustment for different wind speeds was implemented in them, but the number of considered wind speed points for designing the controller parameters is insufficient to apply to various wind speeds. Overall, the small-signal modeling and analysis of a PMSG WT has been rarely researched [8].
- Many literatures on WT control performance issue have been published [9]. A comparison between a PMSG WT and a DFIG WT was studied from the stability perspective in [10], but no method for tuning controller parameters to improve control performance was proposed.
- A small-signal stability analysis of a DFIG WT was presented in references. A controller parameter adjustment for different wind speeds was implemented in them, but the number of considered wind speed points for designing the controller parameters is insufficient to apply to various wind speeds. Overall, the small-signal modeling and analysis of a PMSG WT has been rarely researched [11].
- Variation of wind speed leads to the fluctuation of output from a generator and this is a serious drawback for the low wind speed area [12]. Therefore, power e converters are required to stabilize the voltage.
- The wind energy conversion system consists of four subsystem which are rectifier, Bi-Directional DC-DC converter and power inverter. Output from a wind turbine is in the
- AC voltage and it required to be converted into a DC voltage since boost converter is under DC-DC converter and finally the DC link output is given to Bidirectional DC-DC converter to store in the battery at low wind speed the generated voltage will be low and also Load utilizes power from the battery with the help of inverter [13].

III. METHODOLOGY & RESULTS

3.1 MATHEMATICAL MODELING OF DFIG

The doubly fed induction asynchronous machine (DFIAM) with wound rotor construction is another name for the DFIG. Because DFIAM offers variable speed operations, WECS has recently seen an increase in popularity. Based on synchronous generators, the fixed speed WECS rated the control equipment in accordance with the generator's rating. In order to compensate for variations in load and demand, the power control equipment must supply both active and reactive power.When compared to a DFIG-WT system, which requires a power converter with a 30% rating of DFIG, the full rating power electronic converter used to control active and reactive power is much more expensive for fixed speed WECS. Reactive power error control is added to the voltage stability control. Both the rotor and stator sides can control DFIG.

The main benefit of DFIG is that, thanks to Flexible AC Transmission System (FACTs) devices like the Static Synchronous Compensator (STATCOM) installed at PCC, roughly 70% of power is transferred directly through the stator side. Based on the dynamic regulation of reactance connected in parallel with DFIAM's Stator, the FACTs devices function [10]. Unlike fixed speed synchronous generators, the remaining 30% of the power is fed to the grid with the aid of a power electronic converter attached to the rotor side and rated between 25% and 30% of the DFIG's power rating [7]. DFIG requires its dynamic mathematical model to be accurate in order to forecast its response in different scenarios. The literature contains a variety of models at different angular speeds and in

3.2 DYNAMIC MODEL

Three variable phase quantities are transformed into a set of two stationary vectors called the α-axis and β-axis (clark's transformation) to create the per unit dynamic model of the three phase doubly fed induction asynchronous machine. These fixed vectors are then converted into a rotating frame with coordinates on the d and q axes. The three-phase supply voltages are alternating quantities that, with the aid of Clark's transformation (stationary reference frame), are converted to the α and β-axes as follows:

1) abc to αβo(stationary)

$$\begin{bmatrix} v_\alpha \\ v_\beta \\ v_0 \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{matrix} v_a \\ [v_b] \\ v_c \end{matrix} \qquad (3.11)$$

2) αβo(stationary) to dqoreference

$$\begin{bmatrix} v_d \\ v_q \\ v_0 \end{bmatrix} = \begin{bmatrix} cos\omega t & sin\omega t & 0 \\ -sin\omega t & cos\omega t & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{matrix} v_\alpha \\ [v_\beta] \\ v_0 \end{matrix} \qquad (3.12)$$

3) dqo to abc reference

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} cos\omega t & -sin\omega t & 1 \\ \cos(\omega t - \frac{2\pi}{3}) & -sin(\omega t - \frac{2\pi}{3}) & 1 \\ \cos(\omega t - \frac{2\pi}{3}) & -sin(\omega t - \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{matrix} v_d \\ [v_d] \\ v_q \end{matrix} \qquad (3.13)$$

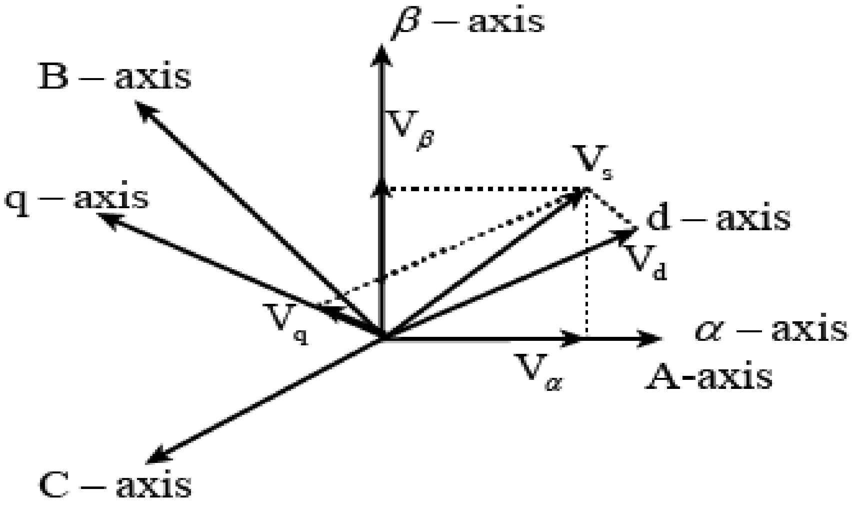

Figure 8: Stator phase voltages along $dq$and $\alpha\beta$-axis.

Assumptions for the Dynamic Model:

- No magnetic flux saturation so the mutual inductance is constant i.e unsaturated.
- Machine windings are connected in star configuration on stator and rotor side hence no zero component.

- $V_a=V_{max}\sin\omega t$, $V_b=V_{max}\sin(\omega t-120)$, $V_c=V_{max}\sin(\omega t+120)$ are balanced three phase stator voltages.

As per park's transformation the three phase stator and rotor voltages transformed to a dqo rotating frame is given the following equations[17],

$$\begin{bmatrix}V_{qs}\\V_{ds}\\V_{os}\end{bmatrix}=\begin{bmatrix}-sin\theta_s & cos\theta_s & 1\\ -sin(\theta_s-\frac{2\pi}{3}) & \cos(\theta_s-\frac{2\pi}{3}) & 1\\ -sin(\theta_s-\frac{2\pi}{3}) & \cos(\theta_s+\frac{2\pi}{3}) & 1\end{bmatrix}\begin{bmatrix}V_{as}\\V_{bs}\\V_{cs}\end{bmatrix} \quad (3.14)$$

dq–axis components of stator voltages in terms of stator line voltages are given as:

$$\begin{bmatrix}V_{ds}\\V_{qs}\end{bmatrix}=\left(\frac{1}{3}\right)\begin{bmatrix}\sqrt{3}sin\theta_s+cos\theta_s & 2cos\theta_s V_{bcs}\\ -\sqrt{3}cos\theta_s+sin\theta_s & 2sin\theta_s V_{bcs}\end{bmatrix} \quad (3.15)$$

dq–axis components of rotor voltages in terms of rotor line voltages are given as:

$$\begin{bmatrix}V_{dr}\\V_{qr}\end{bmatrix}=\left(\frac{1}{3}\right)\begin{bmatrix}(\sqrt{3}\sin(\theta_s-\theta_r)+cos(\theta_s-\theta_r))V_{abr} & 2cos(\theta_s-\theta_r)V_{bcr}\\ (-\sqrt{3}\cos((\theta_s-\theta_r)+sin(\theta_s-\theta_r))V_{abr} & 2sin(\theta_s-\theta_r)V_{bcr}\end{bmatrix} \quad (3.16)$$

θ_s is the angle of reference frame and $\theta_s-\theta_r$is the angle between reference frame and position of rotor. $\omega_s$is the speed of stator flux and $\omega_s-\omega_r$is the relative speed between stator's flux and rotor's actual angular speed.

3.3 METHODOLOGY AND SIMULATION RESULTS

The wind energy conversion systems (WECS) are covered in this chapter. The key components of the WECS are the wind turbine model, the two mass drive train models, the power converter set, and the Matlab/Simulink model with the PI controller and pitch control system implemented.

3.4 PI CONTROLLER CONFIGURATIONS

Fig. 5.1 depicts the typical architecture of a PI control system [32], wherein the error signal e(t) is utilised to generate the integral and proportional actions in a PI controller. The resulting signals are then weighted and summed to form the control signal u(t), which is applied to the plant model. The PI controller's mathematical description is provided as

$$u(t)=K_p\left[e(t)+\frac{1}{T_i}\int_0^t e(\tau)\,d\tau\right]=u_p(t)+u_i(t) \quad (5.1)$$

PI controller, u(t) is the input signal to the plant model, the error signal e(t) is defined as e(t)= r(t)-y(t), and r(t) is the reference input signal.

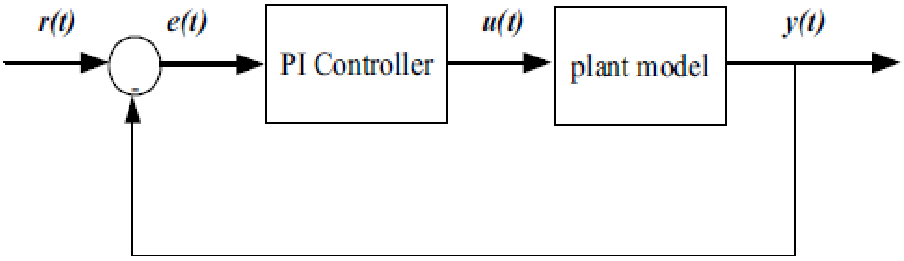

Figure 9: A typical PI controls structure [32]

The PI controllers are the most often type used today in industry. A PI controller is used when:

1) Fast response of the system is not required.

2) Large disturbances and noise are present during operation of the process.

3) There is only one energy storage in process (capacitive or inductive).

4) There are large transport delays in the system.

The controller and feedback transfer functions can be equivalently written as

$$G(s)=K_p\left(1+\frac{1}{T_i s}\right) \quad (5.2)$$

The MATLAB Simulink model of control systems based PI controller shown in Fig. 5.2and Fig. 5.3. That controlled at the grid-side converter, the rotor-side converter and the pitch angle [15].

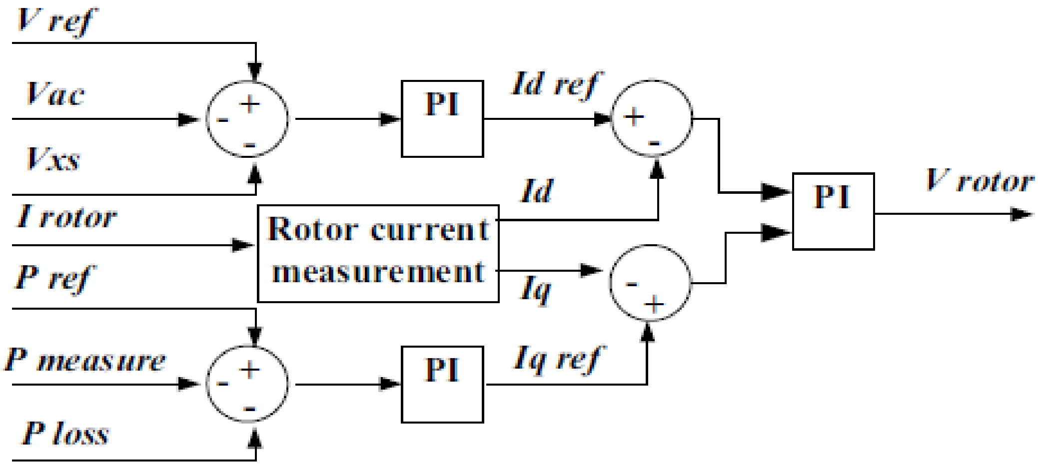

Figure 10: The scheme of the rotor-side converter control system

3.5 ROTOR-SIDE CONVERTER

To independently control the active and reactive power on the stator side, the rotor side converter is primarily used. A stator flux oriented vector control scheme is used to implement the decoupled control method of active and reactive power. The voltage or reactive power measured at the grid terminals, as well as the wind turbine output power, are controlled by the rotor side converter. A predetermined power speed characteristic, also known as a tracking characteristic, is followed by controlling the power [37]. In Fig. 5.2, the control system is displayed. To compare the difference between the q-axis from the VAR regulator (Q), we control the electromagnetic torque into the current regulator on the d-axis. After being converted between Cartesian and d-q axes, the current regulator was converted into voltage.

3.6 GRID-SIDE CONVERTER

The grid side converter is used to regulate the DC bus capacitor voltage. The control system is shown in Fig.5.3.The grid-side converter control fed dc voltage regulator from difference between Vdc and Vdc reference, and transfer into the d-q axis current or the current regulator by PI controller. Then, using PI controller, transfer the regulator again into the d-q axis voltage with the electrical equation of converts not unlike the rotor-side convertor into using the DFIG controlled. The PI controller is controlled at the optimum point for the DFIG systems.

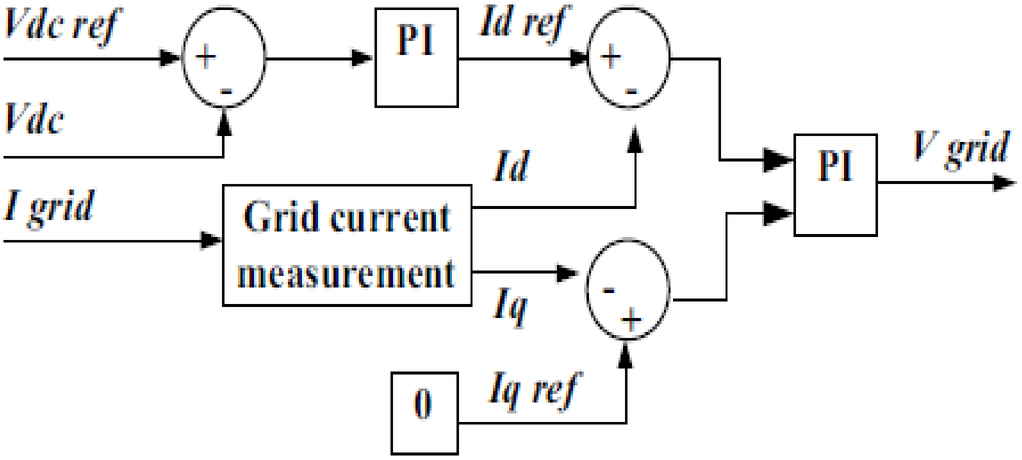

Figure 11: The scheme of the grid-side converter control system

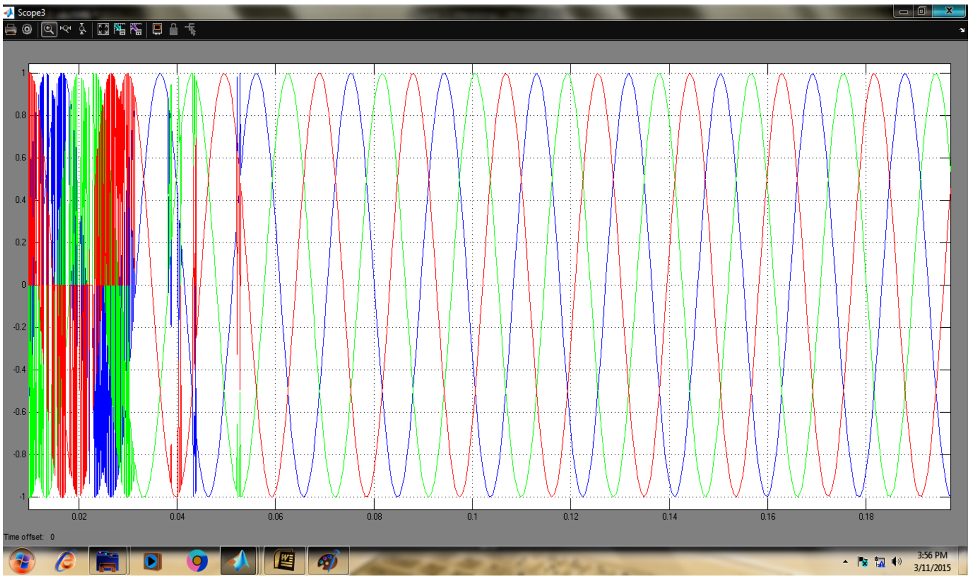

Figure 12: Rotor voltage of wind generator

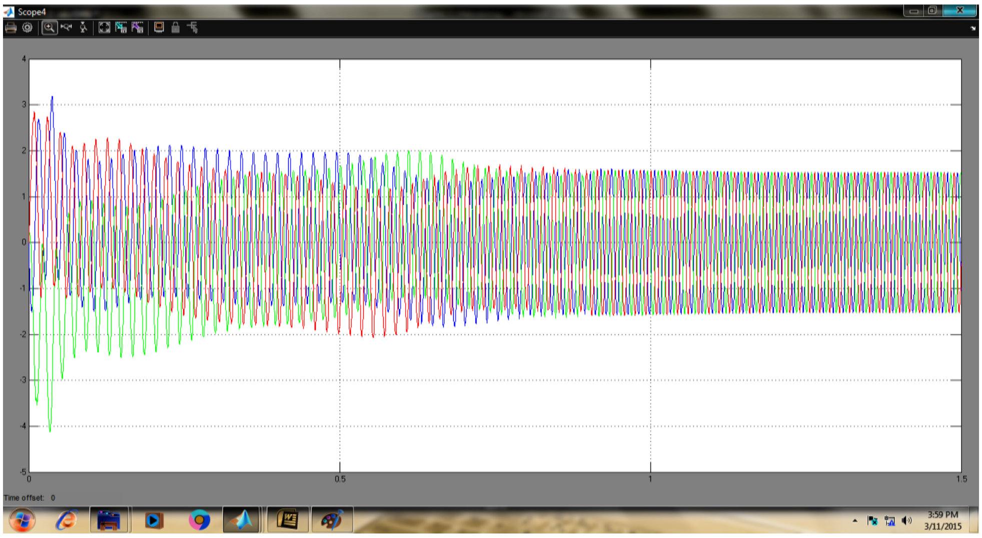

Figure 13: Phase Rotor current Stator active power

Characteristic is shown in fig. 12 and fig. .13 show the characteristic of reactive power.

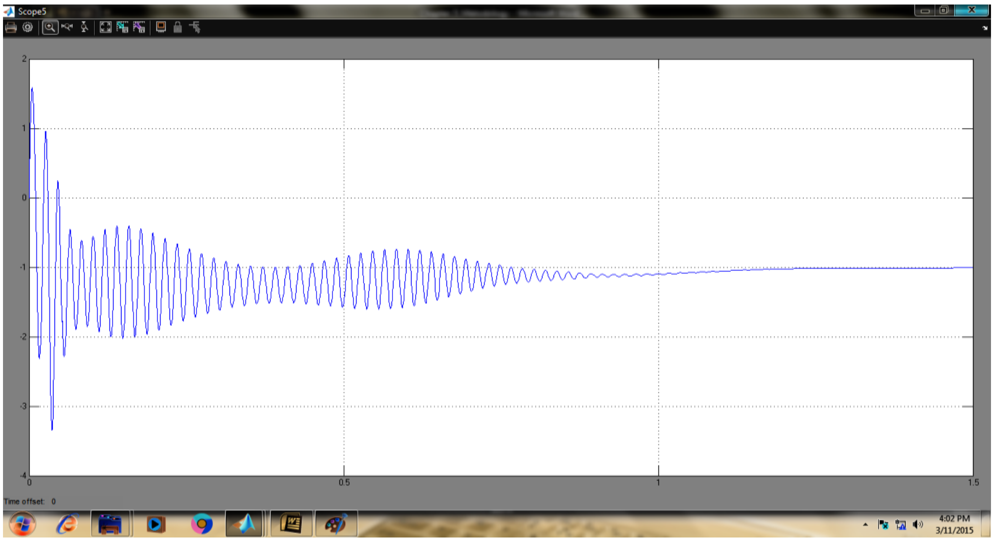

Figure 14: Active power of stator

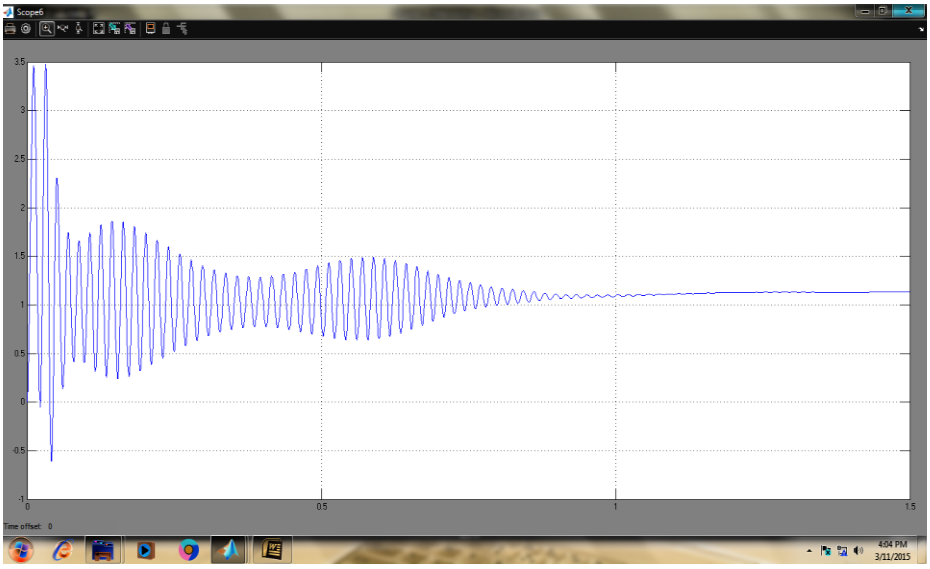

Figure 15: Reactive power of stator

Characteristic of rotor active and reactive power is shown in fig. 16 and fig. 17 respectively.

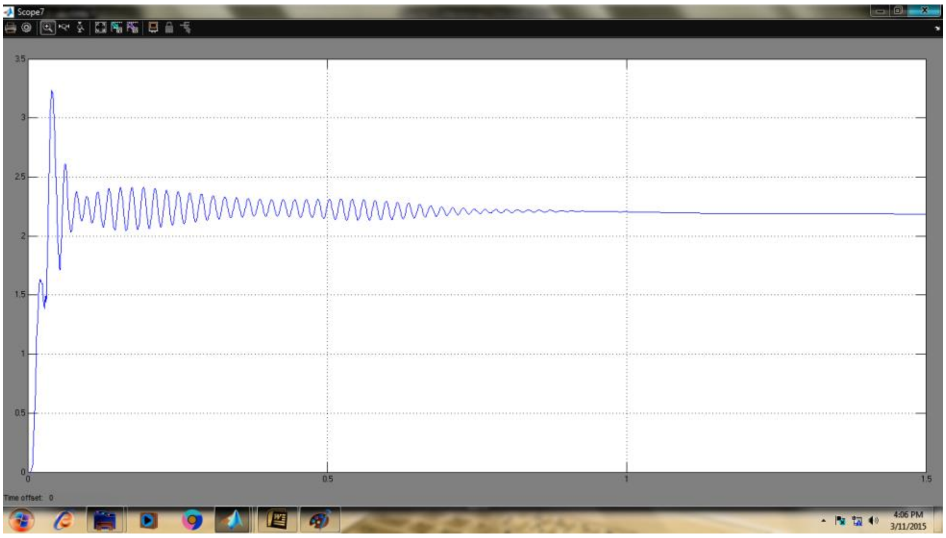

Figure 16: Active power of rotor

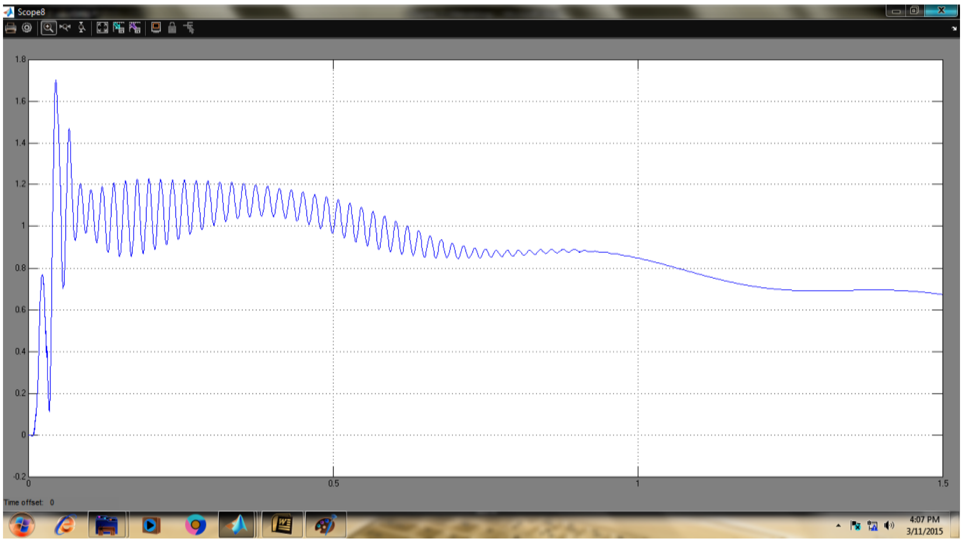

Figure 17: Reactive power of rotor

IV. CONCLUSION

To regulate the amount of power extracted from the wind, wind turbines are modelled. The output power will increase in tandem with the wind's velocity, according to the simulation's results, and a control system will be needed to limit the output power if the wind speed increases even more. In order to guarantee a wind turbine's safe operating area, this is accomplished by modelling the turbine blades. Because of its variable speed capability, higher power quality, and lower converter costs, a DFIG is preferred over synchronous generators.

Improving power quality is the primary goal of this work, which can be accomplished by having a wind power plant that produces consistent output power. Utilising the PI controller simulation and DFIG model, as illustrated in fig. 9. Its active and reactive power results, as displayed in Fig. 13, make it abundantly evident that the obtained power is smooth and stable which demonstrates the excellent power quality this model achieves. Similar to this, Fig. 14's rotor current results demonstrate the DFIG model's stable operation with a PI controller. Our goal was to propose a performance analysis of wind farms using various methodologies. Thus, we must once more replicate the DFIG model using the pitch angle controller displayed in fig. 12. by setting of different pitch angle we can obtain the stable operation of wind power plant. Results of DFIG model with pitch control system shown in fig. 14 clearly shows the stable operation of wind plant. So we can say that we have to fulfil the all objective consider in this work. Our results clearly shows the constant output power generation extracted which shows the good power quality.

- **SCOPE OF FUTURE WORK**

1. To implement fuzzy PI concept in the machine side converter to achieve better performance results.
2. Extraction of the maximum power from the wind using MPPT algorithm.
3. Try to simulate the fuzzy PI controller using improved membership function and rules to obtain a better stability of the dc link voltage.

V. REFERENCES

[1] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, M. A. M. Prats, J. I. Leon, and N. Moreno-Alfonso, "Power electronic systems for the grid integration of renewable energy sources: a survey," IEEE Transactions on Industrial Electronics, vol. 53(4), pp.1002-1016, 2016.

[2] L. H. Hansen, L. Helle, F. Blaabjerg, E. Ritchie, S. Munk, H. Bindner, P. Sørensen, and B. Bak-jensen, "Conceptual survey of generators and power electronics for wind turbines," National Renewable Energy Laboratory, Golden, Co (US) Risø-R-1205 (EN), 2011.

[3] H. Arabian-Hoseynabadi, H. Oraee, and P. J. Tavner, "Failure modes and effects analysis (FMEA) for wind turbines," International Journal of Electrical Power & Energy Systems, vol. 32(7), pp. 817-824, 2020.

[4] F.Spinato, P. J. Tavner, and G. J. W. v. Bussel, "Reliability-growth analysis of wind turbines from fleet field data," in Procedings of Advances in Risk and Reliability Technology Symposium (AR2TS), Loughborough, 2017.

[5] S. Faulstich, B. Hahn, P. Lyding, and P. Tavner, "Reliability of offshore turbines–identifying risks by onshore experience," Fraunhofer institute for wind energy and energy system technology (IWES), Kassel, Germany 2019.

[6] F. Blaabjerg, M. Liserre, and M. Ke, "Power electronics converters for wind turbine systems," IEEE Transactions on Industry Applications, vol. 48(2), pp. 708-719, 2012.

[7] George Weiss and Qing-Chiang Zhong, “Some problems with connecting renewable energy sources to the grid”,19th International Symposium on Mathematical Theory of Networks and Systems-MTNS 2010.5-9th July 2020.

[8] Huang, H.; Mao, C.; Lu, J.; Wang, D. Small-signal modelling and analysis of wind turbine with direct driven permanent magnet synchronous generator connected to power grid. IET Renew. Power Gener. Vol. 6, Pp.48-58, 2012.

[9] Wu, F.; Zhang, X.-P.; Godfrey, K.; Ju, P. Small signal stability analysis and optimal control of a wind turbine with doubly fed induction generator. IET Gener. Transm. Distrib. Vol. 1, pp. 751-760, 2017.

[10] Wu, F.; Zhang, X.-P.; Ju, P. Small signal stability analysis and control of the wind turbine with the direct-drive permanent magnet generator integrated to the grid. Electr. Power Syst. Res. Vol.79, pp. 1661-1667, 2019

[11] Huang, H.; Mao, C.; Lu, J.; Wang, D. Small-signal modelling and analysis of wind turbine with direct driven permanent magnet synchronous generator connected to power grid. IET Renew. Power Gener. Vol. 6, pp. 48-58, 2022.

[12] Y. Ruihong, L. Yanqin, C. Jianxian, "Maximum Power Point Tracking from a Wind Turbine Emulator Using a DC-DC Converter Controlled, " on International Journal of Control and Automation Vol.7, No.1, pp.117-128, 2014.

[13] S. W. Mohod and M. V. Aware,|| Power quality issues & its mitigation technique in wind energy conversion,|| in Proc. of IEEE Int. Conf. Quality Power & Harmonic, Wollongong, Australia, 2018

[14] E. Muljadi and C.P. Butterfield ―Power quality aspects in a wind power plant,|| in IEEE Power engineering June 18-20, 2016.

[15] Arantxa Tapia, Gerardo Tapia, J. XabierOstolaza, and Jose Ramon Saenz "Modeling and Control of a Wind Turbine Driven Doubly Fed Induction Generator" IEEE Trans, Vol. 18, No. 2, pp. 194-204, JUNE 2013.

[16] Yao, C. Yi, D. Ying, J. Guo and L. Yang The Grid-side PWM Converter of the Wind Power Generation System Based on Fuzzy Sliding Mode Control, IEEE/ASME International Conference on Advanced Intelligent Mechatronics, pp. 973-978, 2008.

[17] Shenghu Li, "Power Flow Modeling to Doubly-Fed Induction Generators (DFIGs) Under Power Regulation," Power Systems, IEEE Transactions on , Volume 28, no.3, pp.3292 – 3301, Aug.2013.

[18] L. Fan, H. Yin, and Z. Miao, " A novel control scheme for DFIG based wind energy systems under unbalanced grid condition", Electric Power Systems Research, Volume 81, Issue 2, pp: 254-262, February2011.

[19] Liang Gao; Yangfan Luo, "Simulation of imitation of the characteristics of wind turbine based on DC motor with Matlab," Sustainable Power Generation and Supply, SUPERGEN '09. International Conference on, pp.1 – 5, 6-7 April2009.

[20] Shenghu Li, "Power Flow Modeling to Doubly-Fed Induction Generators (DFIGs) Under Power Regulation," Power Systems, IEEE Transactions on , Volume 28, no.3, pp. 3292 – 3301, Aug.2013.

[21] Vijay Chand Ganti, Bhim Singh, Shiv Kumar Aggarwal, And Tara Chandra Kandpal, "DFIG-based Wind Power Conversion With Grid Power Leveling For Reduced Gusts", IEEE Transactions on Sustainable Energy, VOL. 3, No.1, 2012.

[22] LalitKumar Gautam, Mugdha Mishra "Permanent Magnet SynchronousGenerator Based Wind Energy Conversion System" International Journal of Electrical Electronics & Computer Science Engineering Volume 1, Issue 1 (February2014).

[23] Kaki shanmukesh, Mr.D.V.N.Ananth " Analysis of PMSG Based Wind Energy Conversion System Operating Under Different Grid Fault" International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 9, September2015.

[24] Bouzid Mohamed Amine, Massoum Ahmed, AllaouiTayeb, Zine Souhila "Modelling And Control Of Standalone Wind Energy Conversion System" International Journal of Advances in Engineering & Technology, Jan.2014.

[25] A.Bharathisankar, Dr.R.Seyezhai "MATLAB Simulation of Power Electronic Converter for PMSG Based Wind Energy Conversion System" International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering Vol. 1, Issue 8, November2013.

[26] OmessaadElbeji, Mouna Ben Hamed, LassaadSbita "PMSG Wind Energy Conversion System Modeling and Control" International Journal of Modern Nonlinear Theory andApplication, 2014.

[27] BipinBiharee Srivastava, Er. SudhanshuTripathi "Tracking of Maximum Power from Wind Using Fuzzy Logic Controller Based On PMSG" International Journal of Modern EngineeringResearch.

[28] Nandini.A, Isha T.B "Permanent Magnet Synchronous Generator Based Standalone System" International journal of advanced engineering and globaltechnology.

[29] KajalKushwah, C.S. Sharma "Improvement of Voltage Stability InWECS Using of Two Mass Drive Train And PWM Converter" International Journal ofResearch,2007.

[30] Mirza Mohd.Shadab, Abu Tariq "performance analysis of permanent magnet synchronous generator connected with wind turbine" International Journal of Advanced Technology &EngineeringResearch, pp.541-549,21016.

[31] HyongSikKim, Dylan Dah-Chuan Lu "Wind Energy Conversion System from Electrical Perspective —A Survey" Smart Grid and Renewable Energy, 2010.

[32] C. Carrillo, E. Diaz-Dorado, M. Silva-Ucha and F. Perez-Sabín "Effects of WECS settings and PMSG Parameters in the Performance of a Small Wind Energy Generator" International Symposium on Power Electronics, Electrical Drives, Automation andMotion, In Engineering & Advanced Technology, Volume 3, Issue 4, Aug-Sept, 2015.

[33] Miguel López Jean-Claude Vannier "Stand Alone Wind Energy Conversion System With Maximum Power Transfer Control" Ingeniare. Revistachilena de ingenieria, vol.17 No 3,2009.

[34] Kapil Parikh, Ashish Maheshwari, Vinesh Agarwal "Modeling, Simulation and Performance Analysis of AC-DC-AC PWM Converters Based Wind Energy Conversion System" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-4, September2013.

[35] RaghuvendraKumar Tiwari, Krishna Kant Sharma "Simulation and Modeling of Wind Turbine using PMSG" International Journal of Recent Research and Review, Vol. VII, Issue 2, June2014.

[36] Jay Verma, Yogesh Tiwari, Anup Mishra, Nirbhay Singh " Performance, Analysis and Simulation of Wind Energy Conversion System Connected With Grid" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-6, January2014.

[37] Suji Muhammed Krishnakumari V "Performance Analysis of a PMSG Based Wind Energy Conversion System" International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 8, August – 2014.

[38] PrernaBadoni, S. Bhanu Prakash "Modeling and Simulation of 2 MW PMSG Wind Energy Conversion Systems" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 9, Issue 4 Ver. I (Jul – Aug.2014).

[39] R.Karthick, S.Manoharan, S.Rajkumar "Grid Interface Of A Pmsg Based Wind Energy Conversion System With Power Quality Improvement Features" Journal of Theoretical and Applied Information Technology 20th October2014.

[40] Ali TahmasebiSohi, ShahramJavadi, SZ Moussavi "Power Flow Control in Grid- Connected Wind Energy Conversion System Using PMSG with Harmonic Elimination Added Function" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 10, Issue 1 Ver. II (Jan – Feb.2015).

[41] Abhishek M. Patel, Dr. Jatin J. Patel "PMSG with Inverter using Park's Transformation for Transient Fault Analysis" IJSRD - International Journal for Scientific Research & Development Vol. 3, Issue 03,2015.

[42] Harika G, Jayakumar N, Thrivonasundari D "Design and Simulation of Dual Inverter Based Energy Storage Systems for Wind Energy Systems Using MATLAB/SIMULINK" Int. Journal of Engineering Research and Applications, Vol. 4, Issue 4, April 2014.

[43] V. Arulalan, R. Dhanasekaran "Wind Power Applications in India – Survey" International Journal of Emerging Technology and Advanced Engineering,Volume 3, Special Issue 4, October2013.

[44] P. C. L. Xu, "Direct active and reactive power control of DFIG for wind energy generation," IEEE Trans. on Energy Conversion, vol. 21, no. 3, pp. 750–758, 2006.

[45] L. X. D. Zhi, "Direct power control of DFIG with constant switching frequency and improved transient performance,," IEEE Trans. on Energy Conversion, vol. 22, no. 1, pp. 110–118, 2007.

[46] R. K. Lingling Fan, "Modelling of DFIG based wind farms for SSR analysis," IEEE Trans. on Power delivery, vol. 25, no. 4, pp. 2073–2082, 2010.

[47] J. P. W. Roberto Cardenas, Ruben Pena, "Control of the reactive power supplied by a matrix converter," IEEE Trans. on Energy Conversion, vol. 24, no. 1, pp. 301–303,2009.

[48] M. M. RoohollahFadaeinedjad and G. Moschopoulos, “Simulation of a wind turbine with doubly fed induction generator by FAST and Simulink,” IEEE Trans. on Energy Conversion, vol. 23, no. 2, pp. 690–700, 2008.

[49] J. M. A. B. Miguel Castilla, JaumeMiret and L. G. de Vicuna, “Direct rotor current-mode control improves the transient response of doubly fed induction generator-based wind turbines,” IEEE Trans. on Energy Conversion, vol. 25, no. 3, pp. 722–731, 2010.