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On Line Electrical Grid Interfaced WECS with UPQC for Power Quality Improvement

[1]*Sachinam Tripathi*, [2]*Prof. Amit Kumar Namdeo*
[1]**M.tech Scholar**, [2]**Asst.professor**
[1,2] **Mittal Institute of Technology, Bhopal,**
[1] sachinamiert1994@gmail.com, [2] ec.amitnamdeo@gmail.com

***Abstract*— Unified Power Quality Conditioner (UPQC) is a new member of the custom power device. It is a large, custom power unit featuring integrated shunt and active series filters. Due to the twin inverter configuration and control complexity, the cost of the unit which is higher than other custom power / FACTS systems must be justified by exploring new application areas where the costs of reducing power efficiency are greater than the initial installation costs. Distributed generation (like wind generation) is one sector in which UPQC can consider its potential use. The electricity generation from wind farms has increased considerably. In the case of power failures, voltage slumps and frequency shifts, wind farms have therefore had to be connected to the grid. In order to compensate for the reactive force, additional fault ride capability and preserve Power Quality (PQ) at the point of common interconnection, the application of active filters / custom control devices is becoming increasingly popular in terms of wind generation. As in other forms of distributed generation, wind production often relies on power electronics technology for flexible power grid connection. The use of electronics power in wind generation has increased energy efficiency and capture. The rapid growth in power electronics leading to a high kVA output and a low price per kVA promotes the distribution of such products. This thesis is focused on the grid interfaced wind energy system. The UPQC is used here for improving the power quality issue followed by the wind energy system. The whole system is modeled in the MATLAB for validating the performance of the proposed system.**

Keywords*— PQ,FACT,WECS,CPD,UPQC,SEUC.

I. INTRODUCTION

Since ancient times, natural wind has been a precious mechanical power source. Today's wind turbines of large capacity are eligible to power the grid as a result of the developments in engineering and technology. Wind power is being used to generate electricity with transformation of mechanical power, which is one of the world's fastest growing electricity generation sources. For at least 3,000 years, people have been using wind power. Wind power was used for the pumping of water or the grinding of grain until the twentieth century. The fluctuating wind energy tends to be disadvantageous in the initial phase of modern industrialization, and therefore fuel fired engines and electrical grid sources that provided a more reliable electricity supply have been replaced. Wind is the flow of air that is normal. The irregular heating of the earth's surface by the sun causes it. Since the surface of the earth is covered by various kinds of soil and water it absorbs solar energy at various rates. The air on top of the soil gets faster over the water during the day than the night. The hotter, heavier air rushes, producing winds over the planet and increasing.

The breeze is reversed during the night, since the air cools over land faster than over water. Similarly, the strong winds around the planet are created because the earth is more warmed by the sun near the earth's equator than the earth close to the north and south of the poles. Now days, the primary use of wind energy is power generation. Wind power is dubbed a source of renewable energies, as long as the sun shines, wind can blow.

Background of WECS :- In December 1952, wind power development started in India when Maneklal Sankal chand Thacker, a distinguished power engineer, launched an explorative project on wind power in India, together with the Indian Conseil of Science and Industrial Research (CSIR). In accordance with the CSIR established a wind power subcommittee in the country. Nilakantan's task was to examine the resources available which can be used in combination with the analysis of the economic potential of wind energy. In India, with the help of the Indian Meteorological Department, the subcommittee studied and carried out comprehensive surveys of potential wind energy uses and successfully developed and tested large wood-and-bamboo windmills.

Fixed Speed Induction Generator (FSIG):-This is the most traditional generator of wind turbines. An induction machine with a squirrel cage is run at a super-sync speed to supply grid power. The speed of the rotor is almost constant in this system type. It is thus referred to as the Fixed Speed Induction Generator (FSIG). The rotor is bound by a gearbox to the wind turbine. At the generator grid connection point a power factor correction condenser is connected. Figure 1 illustrates the typical wind turbine system for fixed speeds.

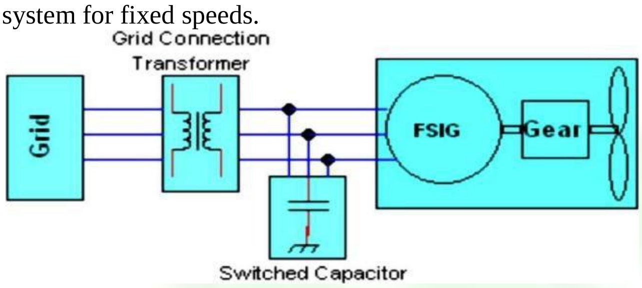

Figure 1: Schematic Diagram of Grid Interfaced SFIG

II. LITERATURE REVIEW

José L et.al [8] revises simulation, optimization, and existing tools to simulate and design self-sufficient hybrid electricity production systems. Y. Amirat et.al [9] designed to describe the various types of defects, their signatures generated and their diagnostic systems in short order. Wind Energy Conversion Systems (WECSs) constantly need to reduce operational and maintenance costs. This cost reduction would be most effective if the condition of those systems were continuously monitored. This makes it possible to early detect generator health degeneration, facilitates proactive reactions, minimizes downtimes and maximizes productivity. Wind generators also cannot be accessed because they are located on very high towers, which normally reach a height of 20 m or above.

III. IMPACT OF WECS ON POWER STABILITY

Power systems are complex systems that evolve with the growth of the economy over the years and are constantly increasing the demand for power. More energy is required to meet basic needs and achieve enhanced standards of human rights with growing populations, and the industrialization of the developing world. The architecture of a state-of - the-art power system has become highly complex to make energy available efficiently with low carbon emissions from renewable [24].

In recent years, wind power plants and other power generating units have increased rapidly. Moreover, the quality of power when the grid includes wind turbines is depending heavily on the interaction between wind turbines and the grid. The main influence of the wind turbine integration on the grid is linked to fluctuations and voltage changes, harmonic contents, flicker and peaks in terms of electricity quality. Such disturbances may be determined by the technical features and meteorological conditions of the wind turbine. These can be classified as: turbulence, or shadowing of a tower, constant variation in output power due to tower effect, electrical components ' performance, for example, rotor mechanical performance, transformers, and aerodynamics.

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Annual wind farm energy production does not correspond to the sum of the generator nameplate ratings multiplied in one year by the total number of hours since wind speed varies. The wind farm capacity factor is the annual maximum ratio of actual productivity to theoretical maximum. For values at the top of a scale at especially desirable sites, the level of capacity factor ranges from 20 to 40%. Variation of the wind on site and the generator size affect the capacity factor by several parameters. A smaller generator would be cheaper and have a higher capacity factor, but would generate fewer (and therefore less) power in high winds. In contrast, large generators would cost more but produce little extra power and could break out at low wind speed. The optimum capacity factor of the wind farm would therefore be approximately 20–35 % [25].

Issue in Wind Energy based Power System:-Unlike traditional energy sources, wind farms supply the upstream grid with real electricity variations, and at the same time reactive power consumption relates to real power generation in a number of types of wind power systems. This variation in power causes voltage changes that affect the electric power system and customers. On the other hand, through use of electronic power in wind generation systems integrates the power system with voltages and current harmonics. Because wind energy is an uncontrollable source of energy, voltage stability and transient stability can lead to problems. As the number of wind farms connected with the grid rise rapidly, there is clear importance and need for the study of wind farms connected to power systems as well as the increasing power rates for single wind farm and the weakness of the upstream power grid, where the wind turbine connects. Wind farm connections to electric energy systems affect the system operating point, the real and reactive power charging flow, nodal voltages and electricity losses. At the same time, wind power generation has a wide range of characteristics [26]:

Location of WECS in Power System:-The effect of a wind farm on the power supply network depends on the position and relationship between wind turbine output and load consumption of wind turbines in relation to demand. Wind power affects the network power flow, like any load or generation, even changing the direction of power flow in parts of the network. The changes in power lines can lead to power losses or advantages. Increased production of wind power may affect bottlenecks situations. Depending on its location, wind power may reduce bottlenecks situations in its best possible way, but at another location, bottlenecks situations are more common. There are a wide range of ways to optimize the use of existing lines, such as online data, FACTS and wind power generating control. Grids can nevertheless be strengthened in order to ensure effective and secure transmission. Grid extensions are often required in order to take advantage of wind energy, when new generation is installed in poor grids far from the load centers.

In particular, the same thing applies to traditional wind farms or other power stations. The cost of wind power system refurbishment is therefore highly dependent on the position of the wind turbine relative to the load and grid facilities and numbers have to be expected to differ between countries. Wind turbines can be built with current technology to meet customer requirements, including voltage drops, adaptive power supplied, terminal voltage regulation and involvement in the system's performance and speed control process of SCADA (Supervision Regulation and Data Acquisition),[27-29].

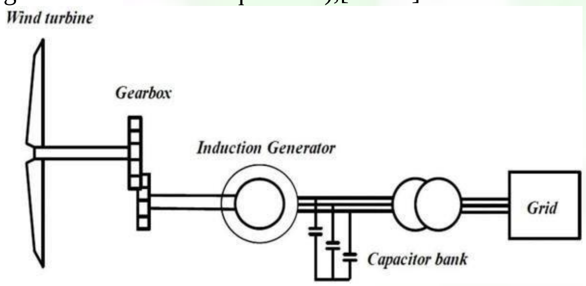

Figure 2: Fixed Speed Induction Generator based WECS

Variable Speed WECS Variable speed principles enable the wind turbine to run at the best peak speed ratio and therefore the optimal power coefficient for a wide range of wind speeds. The DFIG and the synchronous generator are the two most commonly used wind turbine variable speed terms.

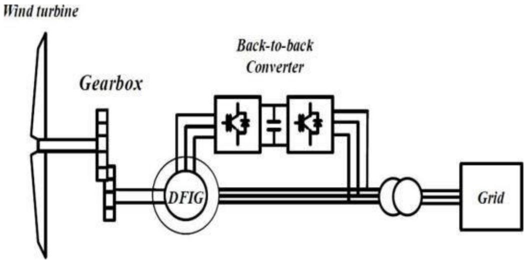

Figure 3: DFIG based WECS

IV. UNIFIED POWER QUALITY CONDITIONER

A UPQC is relatively a new member of the family of custom power devices. The shunt and series compensators were integrated simultaneously in UPQC. The concept of UPQC is firstly introduced in 1996 so it is speculated that can address almost any Power Quality (PQ) problems. PQ problems generally occur either because of a distortion in voltage of supply or due to the absence of loads current. Because UPQC has both series and shunt compensation technique hence it once mounted at the point of common coupling (PCC), it can handle supply voltage and load current issues at the same time. It can protect sensitive loads against events of power quality, which increase on the utility side and simultaneously prevent disturbances on the load side of the device. This chapter discusses the UPQC's architecture, various control strategies and possible new applications.

The structure and working principle of a UPQC the UPQC is a compensator based on power electronics and operates on the effective filtering concept. It is a mixture of Shunt (SHUC) and Series (SERC) compensator in cascaded through a DC link condenser. There are two types of UPQC configurations are possible depending on the position of the SHUC and the SERC. Figure 4.1 and Figure 4.2 show schematic diagrams of both configurations. All UPQC components consist of an IGBT-based bridge inverter which depending on the control scheme and it can operate in a Voltage or Current Controlled Mode. The Inverter I (Series Compensator (SERC)) is connected with alow-level LC filter and a transformer at the supply voltage side. The Inverter II (Shunt Compensator (SHUC)) is connected to the load side with a smoothing inductor parallel to the load. The SERC acts as a controlled voltage source and offsets all voltage disruptions in the grid. The SHUC works as a controlled current source and offsets reactive power or harmonic from the load side. This serves as a real power path for maintain the DC link voltage at a constant value with constantly charging the DC link condenser.

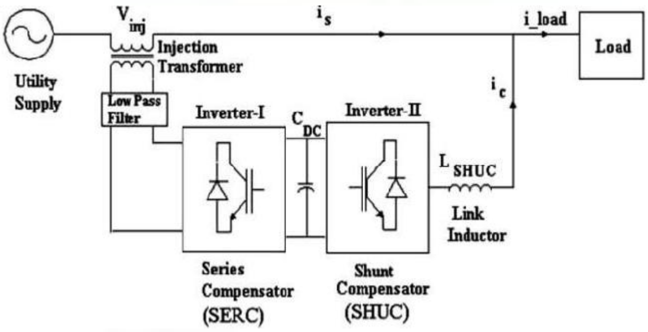

Figure 4: Structure of Right Shunt UPQC in Grid

The reactive power compensation is provided by SHUC and also current harmonic compensation in the load side. The position of the SHUC and SERC for the left shunt configuration (Figure 4) will be changed as per the concern type of utilization. The many work recorded on the UPQC was the use of the right shunt UPQC, because of its characteristics are more conducive to the use of load reactive energy and harmonics than those from the left shunt UPQC for the normal use and the voltage disturbance on the spring side has to be compensated by SERC, When UPQC application for a distribution system is considered.

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The left shunt configuration of UPQC shall be preferred when UPQC catered for two different loads, one being voltage-sensitive and the other generating harmonics.

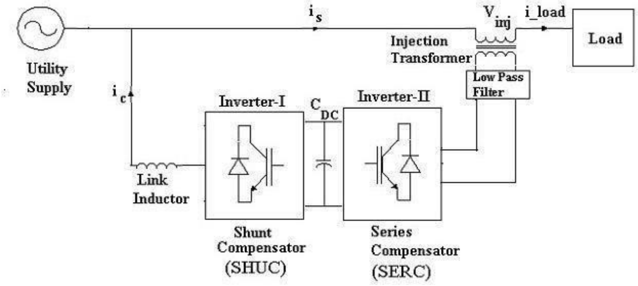

Figure 5: Structure of Left shunt UPQC

Application of UPQC

Because of the flexibility of the UPQC, various applications can be found in traditional energy systems. The new application areas of this flexible tool are worth exploring. This system allows multiple users to choose different electricity value. A UPQC, which guarantees critical users high quality capacity, is a key element of the customer quality control centre. The micro-grid consists of small, local load generators. The UPQC avoids reactive power, load-current harmonics and voltage distortions, when connected to a high-frequency common bus. Figure displays the high-frequency micro-grid.

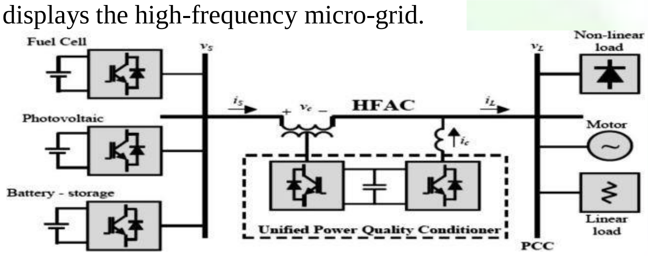

Figure 6: Grid interfacing concept of AC micro-grid with UPQC

V. SIMULATION RESULTS

The proposed model is simulated in MATLAB software. Figure 7 shows the SIMULINK model of UPQC based WECS

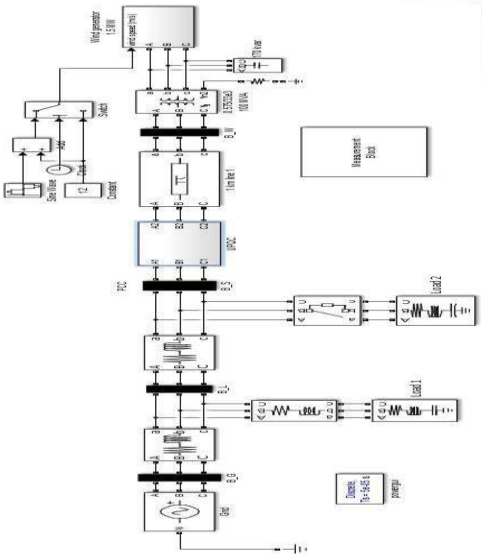

Figure 7: SIMULINK model of proposed Grid Interfaced UPQC based WECS

The whole system is buildup in three major sections. First section is the modeling of wind energy conversion system. In this section discussed how the wind energy is converted into electrical energy. Second section is based on the application and working of UPQC. Third is the interfacing of the grid to the proposed system.

Modeling of WECS

Figure 8 shows the SIMULINK model of the wind energy conversion system. The system consists of 1.5 MW mechanical turbines connected with three phase induction motor.

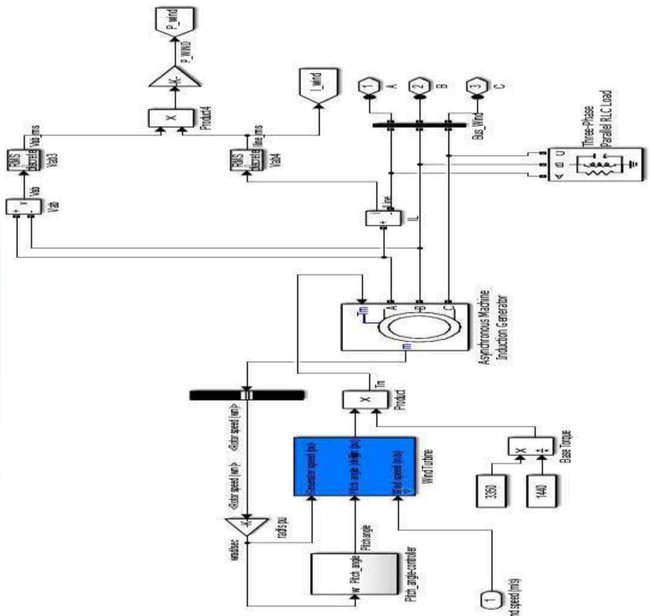

Figure 8: SIMULINK model of IG based WECS

The transfer of wind energy is the core part of the entire simulation. This is focused on the engineering of electromechanical conversion. The mechanical turbine and electrical generator are combined with the wind power conversion system. Two sections are used in the simulation, one is for the section of the driving train and the other is the section of the electrical generator. In particular, the wind turbine driving train (mechanical components) consists of a blade-pitching mechanism, a blade core, a rotor shaft (relatively long for wind turbine converters). The design of the drive train involves the turbine and the generator in this report. The moment of inertia of the wind wheel (blade-fed hub) is about 90% of the total moment of the plane, while the time of the inertia rotor generator is about. For conversion of mechanical power here induction generator is used. The shaft of the turbine is directly coupled to the rotor of the induction generator. Due to rotation of the turbine the connected rotor is rotated and thus the emf is induced in the generator which further produces the electricity by the induction generator.

Modeling of UPQC

Unified Power Quality Conditioner (UPQC) plays the major role in this simulation. It compensates the series voltage and shunt current when sudden change of the load appear in the proposed work. Figure 9 show the SIMULINK model of the UPQC. It \consists of two back

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to back converters with common DC link capacitor. The back to back converter is posses with the voltage source inverter. One converter is connected to the grid side which is calls series converter and other is connected to the wind side which is known as shunt converter.

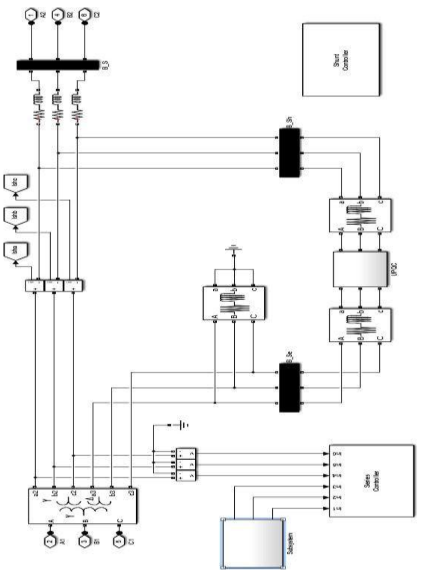

Figure 9: SIMULINK model of UPQC

Figure 9 shows the SIMULINK model of unit vector calculation block. This block produces the reference current and reference voltage for the simulation with the help of phase locked loop (PLL). The control method is based on the extraction of the distorted wave of the source side. The PCC's 3-ph distorted source voltage contains basic component and distorted component. The input voltage is sensed and multiplied by gain equal to 1/*Vm* to get unit input voltage vectors *Uabc*, where *Vm* is equal to the peak amplitude of the fundamental input voltage. Such vectors ofthe input voltage system are passed to the phase locked loop (PLL) stage. The unit vector templates are given with the right phase delay.

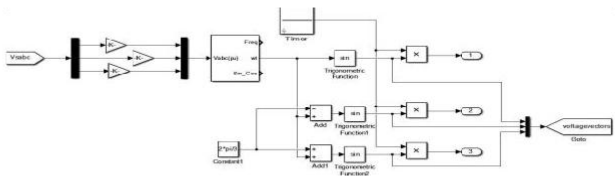

Figure 10: SIMULINK model of Unit Vector Calculation Block

Figure 11 shows the PWM generation for the series converter switch of the back to back converter which is used in the UPQC.

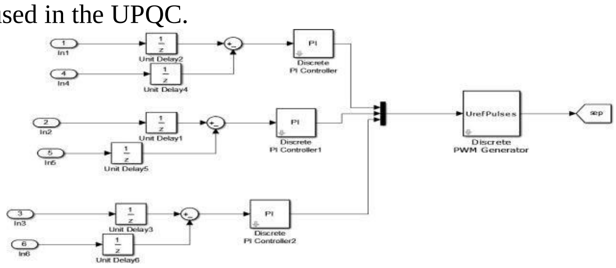

Figure 11: SIMULINK model of Series Controller PWM block

For generation of PWM here we use the comparator block with calculated unit vector with actual voltage at the source end. The error is controlled by the PI controller and then it is superimposed by the carrier wave to produce the PWM signal for the series converter to compensate the voltage variation in the proposed work. Figure 12 shows the shunt controller controlling block. This is used for the controlling the current of the system. For controllinghere the instant *p-q* theory is used.

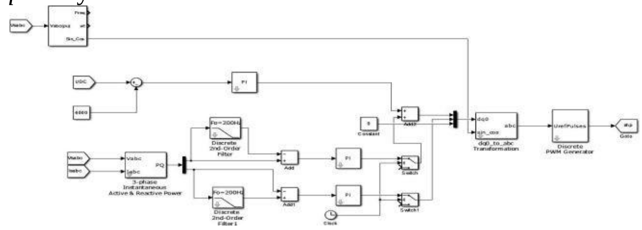

Figure 12: SIMULINK model of Shunt Controller PWM Block

Here in this block firstly calculate the total active and reactive power of the supply system. The founded value is then passed by the low pass filter further we calculate the d-q axis current of the supply system. This is the reference signal of the system. With the help of inverse park transform we found the reference current of the system. This reference current is further compare with the actual current for generation the PWM of the shunt controller.

Figure 13 shows the back to back converter which is used in this UPQC. Here IGBT switch is used due to high voltage retentive characteristics.

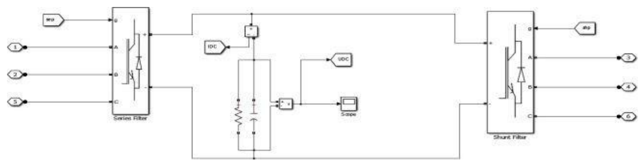

Figure 13: SIMULINK model of Back to Back Converter Block

Result Analysis:- In this section discuss the various result obtained by the simulation of the proposed work. Table 1 show the parameter which is used in this simulation. The whole model is simulating in the MATLAB version 8.2 with ode23tb solver.

Table 1.1: Parameter of the SIMULATION

Parameter	Value
Wind Energy Conversion Parameter	
Output Power of Wind Turbine	1.5 MW
Induction Generator Rating	7.5 kW, 400 V, 50 Hz, 1440 RPM
Pitch Angle	0 Degree
Load at Wind Side	10 kW, 50 Hz, 1000V
Transmission Line Parameter	
Length of Line	1 km
Line Parameter	r = 0.115Ω/km, L= 1.05mH/km
Grid Voltage	33 kV, 50Hz
UPQC Parameter	
Series Controller PI parameter	k_p=100, k_i=10
Carrier Wave Frequency	1080 Hz
Shunt Controller PI Parameter	k_p= 200,k_i=10
DC Link Capacitor	300μF
Switch	IGBT
Series Filter Choke	L=1 mH, r =1Ω
Shunt Filter Choke	L= 1mH, r=1Ω

Figure 14 shows the active and reactive power of the proposed system. As we know that the induction generator produces the reactive power to the grid. But due to presence of the UPQC it is compensated and makes it constant as shown in the result.

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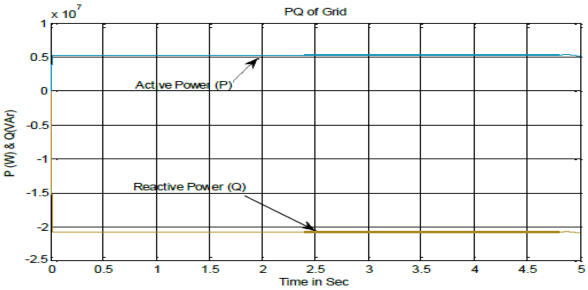

Figure 15: Active and Reactive Power of the grid of the Proposed System

Figure 16 shows the grid voltage of the proposed system for entire simulation.

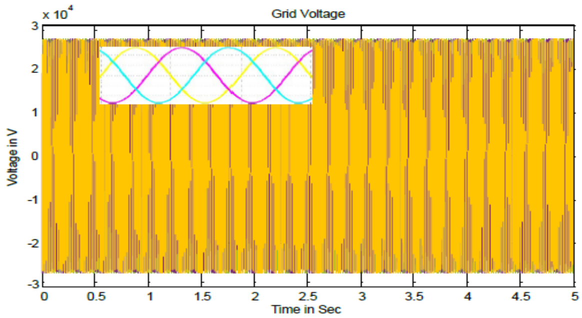

Figure 16: Grid Voltage of the Proposed System

Here it is clearly seen that the overall voltage of the system is always in sinusoidal in nature. So due to presence of the variable output wind generation integration doesn't affect the system. Similarly in the current of the grid is also a show the same result. Figure 17 shows the current performance of the proposed system.

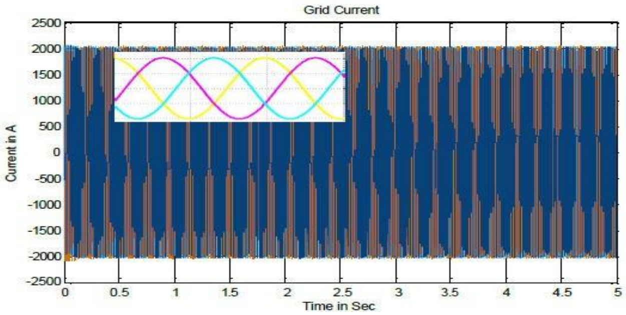

Figure 17: Grid Current of the proposed System with UPQC

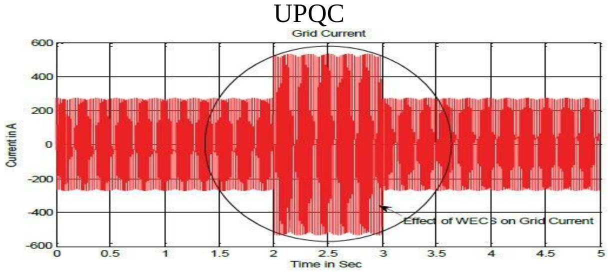

Figure 18: Grid Voltage without UPQC in the proposed system

Figure 18 shows the proposed model without implementation of UPQC in the system. Here it is clearly seen that the effect of UPQC in the grid. Without UPQC the level of the current get decrease and also when the load is sudden applied the level increase. This makes system failure at any time and retard the power quality of the system.

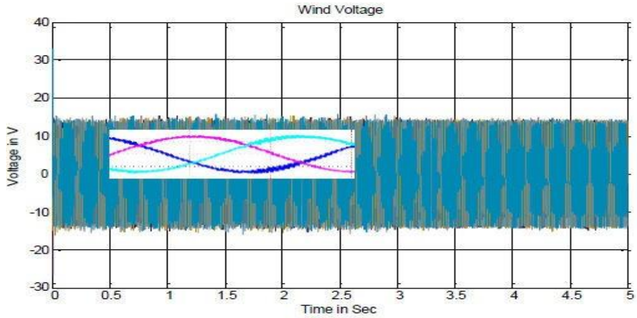

Figure 19 Terminal Voltage of Induction Generator.

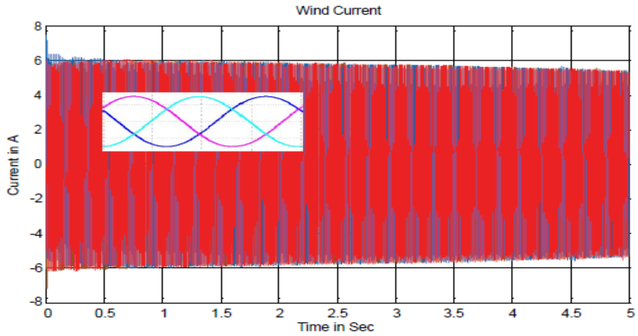

Figure 20: Terminal Current of the Induction Generator

Figure 20 shows the terminal voltage of the induction generator which is used in this simulation for converting mechanical power to the electrical power. Figure 5.13 shows the terminal current of the Induction generator.

Result Comparison

Table 2 shows the comparative result analysis with the previous work.

Table 2: Result Comparison

Parameter	Previous Work	Proposed work
Grid Voltage	30 kV	33 kV
Compensation Technique used	DVR	UPQC
Total Capacity	1 MW	1.5 MW
Reactive Power	1.75 MVAr	2.1 MVAr

VI. CONCLUSION AND FUTURE WORK

Custom power devices such as DVR, D-STATCOM, and UPQC can improve the distribution system's power quality. There is an option to choose specific model power devices with specific compensation depending on the power quality problem at the load or at the distribution system. Unified Power Quality Conditioner (UPQC) is a mixture of series and shunt APF, which compensates imperfections in the distribution system for supply voltage and load current. The UPQC included in this project is a multifunctional power conditioner that can be used to compensate for various voltage irregularities in the power supply, to correct any voltage variations and to avoid harmonics. Custom power devices such as DVR, D-STATCOM, and UPQC can improve the distribution system's power quality. There is an option to choose specific model power devices with specific compensation depending on the power quality

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Future Scope

There are many aspects by which it can further expand the proposed work. Such of them are:

- To improve the device's performance, an alternative DSP control could be developed for the UPQC. Because of the dead time of the IGBT switches, the series compensator control could be modified to compensate for the distortion of supply voltage and injected voltage.
- As part of this research work, the UPQC prototype is designed and could be used in the laboratory for future research work in this area. The investigations performed on the implementation of the UPQC for efficient grid integration of the wind generator provided valuable insights and a laboratory experimental set-up could now be achieved more easily given the simulation experience.
- New vector control schemes could be developed for the UPQC-WG to effectively control the reactive energy at the grid connection as a function of voltage and actual power output, and to control the variation of the stator terminal voltage.

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