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Improvement of Power Quality in Wind Energy Conversion Systems

Yogananda. B. S[1], Dr. K. Thippeswamy[2]
[1]Assistant professor, Department of EEE, SSIT, Tumkur
[1]Selection Grade Lecturer, S.J Govt.Polytechnic, Bangalore

Abstract: Wind Energy Conversion Systems (WECS) show variability in their output power as a result of changing their main engines (wind speed). This introduces a new grid uncertainty factor and poses many challenges to electricity system designers and utilities in terms of grid network integrity, ie power system security, power system stability and power quality. This paper discusses the various challenges of wind energy when integrated into the grid and identifies different mitigation strategies for its smooth integration.

Keywords: wind energy system, Power quality, Power filters, Reactive Power, controllers

I. INTRODUCTION

As a result of environmental concerns and the energy security effort, efforts are being made to integrate renewable energy sources into the grid. Wind energy stands out among renewable energy sources due to its technological maturity, solid infrastructure and relative cost competitiveness. Wind energy is expanding at a rate of 20% per year at the moment and is projected to increase at a rate of 12% per year in the future.

Due to the unpredictable nature of wind resources as a result of constant fluctuations in weather conditions, the output power of WECS varies. The intermittent and diffuse nature of wind energy adds a new level of uncertainty to the grid, possibly affecting grid integrity, such as power quality, system security and power system stability.

Wind energy is controlled by nature and this can affect the electrical system. To effectively replace wind turbines with conventional conventional generators, they must be able to provide small ancillary services, control key voltages, ensure the load that follows, maintain the grid frequency and contribute to the fault current. all services performed by conventional power stations. Wind energy penetration is still low (maximum 20% in Denmark). Auxiliary services are largely supported by conventional power stations. When the level of penetration increases, the technical implications for network integrity may arise, this must be understood. This therefore implies the need for certain technologies that will allow the smooth and correct integration of WECS into the network. Therefore, the necessary specifications for such technologies must be understood and appropriate.

This study discusses the many issues WECS faces when integrating directly into the network and defining the parameters and variables required for smooth integration using various mitigation problems.

II. LITERATURE SURVEY

A technical overview of energy issues related to renewable energy-based distributed generation systems, and how custom power devices (CPDs) such as STATCOM, DVR, and UPQC can help improve energy quality. One of the most important factors for the custom selection of power devices is the IEEE and IEC standards for grid-connected renewable energy systems. The issues of integration with photovoltaic and wind systems are examined, as well as related PQ issues. The relevance of CPDs to improving the integration of renewable energy sources and to providing high quality energy through custom power parks is discussed.

The wind energy conversion system (WECS) is interconnected with the utility system through electronic power converters, which plays an important role in the integration of wind energy into the electricity grid. The main power quality disturbances due to the integration of WECS in the network are the power fluctuations and harmonics. In order to maintain the network synchronization and to maintain the total harmonic distortion (THD) within operating limits, suitable control circuits for the side-grid converter are required. The main objective of the controller from the network side is to control the power provided to the network, the synchronization of the network, the provision of high quality power to the network and the observance of the compliance with the network code. In this document, the control schemes used in the grid-connected wind energy conversion system to control the inverter on the generator side and on the grid side are thoroughly reviewed.

The paper presents a comparative study of rotor flow oriented and direct torque control (DTC) control techniques applied to the Permanent Magnet Generator Side Frequency Converter (PMSG) for application of wind turbines. For the peripheral converter, various control schemes are developed mainly based on voltage oriented control (VOC) or direct power control (DPC). The performance of the VOC-based control system depends essentially on the method used for the current control.

A comparative study is made between them and the findings are presented in a table. The requirements for the integration of the wind turbine in the network, the network synchronization and the requirements of the monitoring unit are also discussed.

The high cost of fossil fuels, together with environmental concerns, require a significant increase in the use of renewable energy sources. One of these wind projects has earned a significant amount of money. Due to the speed behavior of wind turbines, it is difficult to achieve good power quality. The voltage and power of the components connected to the wind turbine are affected. A new technique and control must be designed to handle fluctuations and increase wind energy production. Potential excitation induction generators are also used for safety reasons.

In addition, many energy storage technologies are used to compensate for changes in wind energy. A static compensator is used for harmonic current injection and correction of reactive power. Fault tolerance is also increased, in addition to improving the power quality of wind turbines. The wind turbine's reactive power correction handles a dynamic voltage rectifier.

Wind Energy Conversion Systems (WECS) show variability in their output power as a result of changing their main engines (wind speed). This introduces a replacement factor of grid uncertainty and poses many challenges to electricity system designers and therefore utility operators in terms of grid network integrity, ie grid security, grid stability and power quality.

III. DESIGN AND IMPLEMENTATION

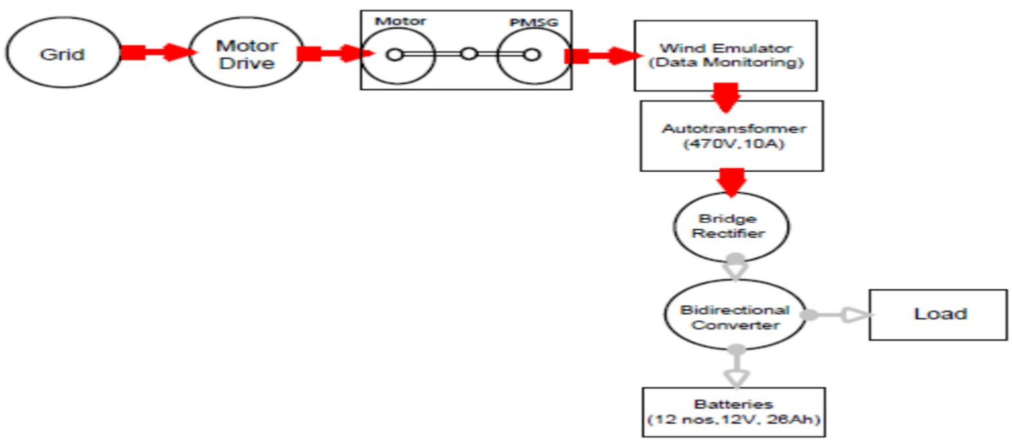

Figure 1: Block Diagram of Proposed work

A. Power Analysis with a Function of Wind Speed

The speed at which air rushes rapidly to a point above the Earth's surface is referred to as wind speed. Due to this relationship, small differences in wind speed result in large power inequalities. The power generated by the wind is related to the velocity cube and depends to a large extent on the wind speed.

The following equation determines how much power is available in the wind.

P =1/2 ρAv3

where

P= power

ρ = density

A= rotor area

v = wind speed.

The density of the air changes with altitude, temperature, and weather fronts

Table 1: Power Analysis with a Function of Wind Speed

Wind Speed	Turbine Power	Generator Power
3.0	31.9	3.0
5.0	147.5	14.5
7.0	404.8	42.3
9.0	880.3	68.8
11.0	1570.8	123.8
11.0	1570.0	157.7

Table 1 shows the power analysis with a function of wind speed. It shows the result of turbine power and generated power with respect to wind speed. The corresponding graph and practical view is shown in the Figure 2 and Figure 3.

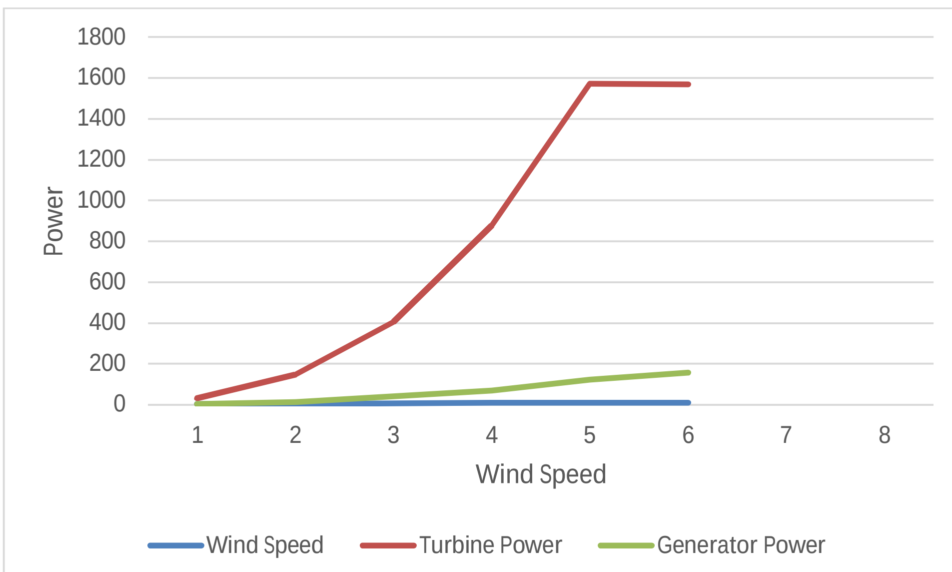

Figure 2: Power Analysis Function of Wind Speed

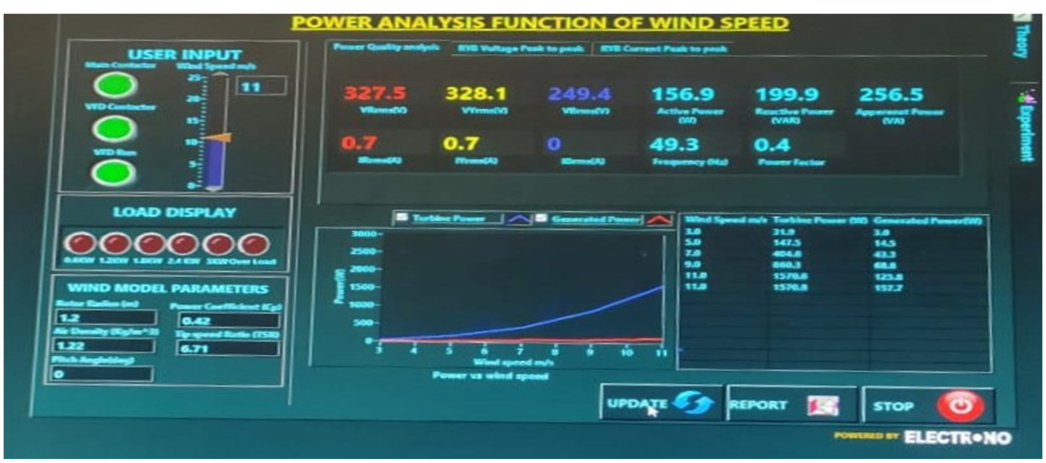

Figure 3: Result of Power Analysis Function of Wind Speed

B. Angular Velocity Analysis Function of Wind Speed

The turbine uses wind energy to push it to the desired angular operating speed. Passes nominal co-efficiency as it accelerates. If the turbine is not loaded, it will continue to accelerate until it reaches the speed ratio of the tip. The angular velocity of the turbine can quickly exceed the design limits in strong winds, so it should not be used without load. The peak speed ratio for constant will be high at low wind speeds and will decrease as the wind speed increases. Mechanical power increases when the wind speed increases from a low value, due to both the increasing wind power and the higher Cp values. The angular velocity of the turbine can quickly exceed the design limits in strong winds, so it should not be used without load. With the generator connected to the mains, normal operation will have an almost constant angular velocity, depending on the generator.

The higher velocity, higher the output, higher the wind speed and this result shows in Table 2. The graph of angular velocity versus wind speed along with it's result is observed in Figure 4 and Figure 5 respectively.

Table 2: Angular Velocity Analysis Function of Wind Speed

Wind Speed (m/s)	Turbine AV	Generator AV
3	16.4934	1.9443
4	21.9911	3.4725
5	27.4889	5.3272
6	32.9867	15.289
7	38.4845	20.7386
8	43.9823	27.0247
9	49.4801	50.3819
10	54.9779	61.7347
11	60.4757	74.6168
12	65.9734	129.7508

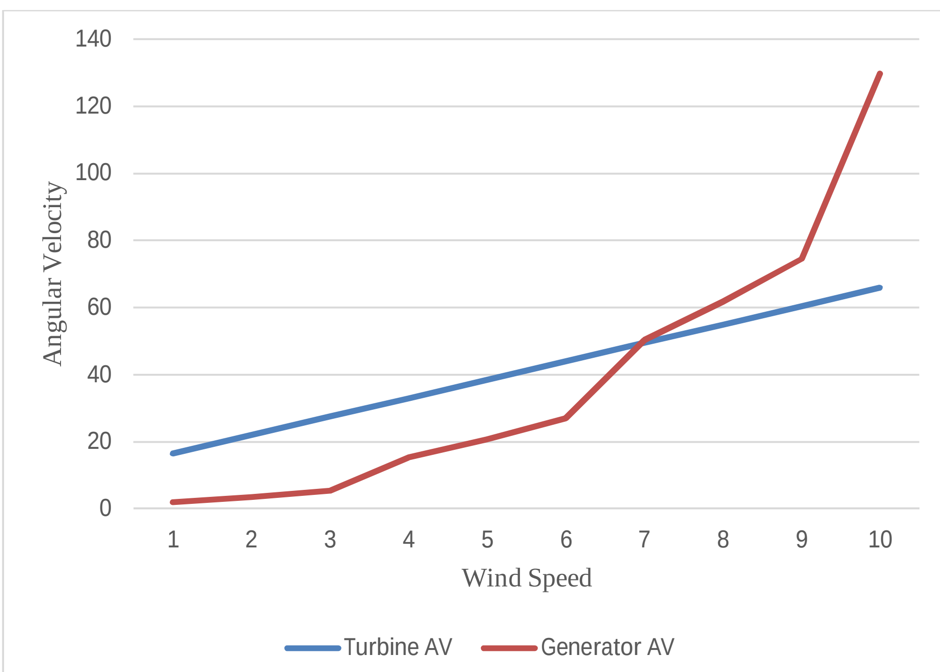

Figure 4: Angular Velocity Analysis Function of Wind Speed

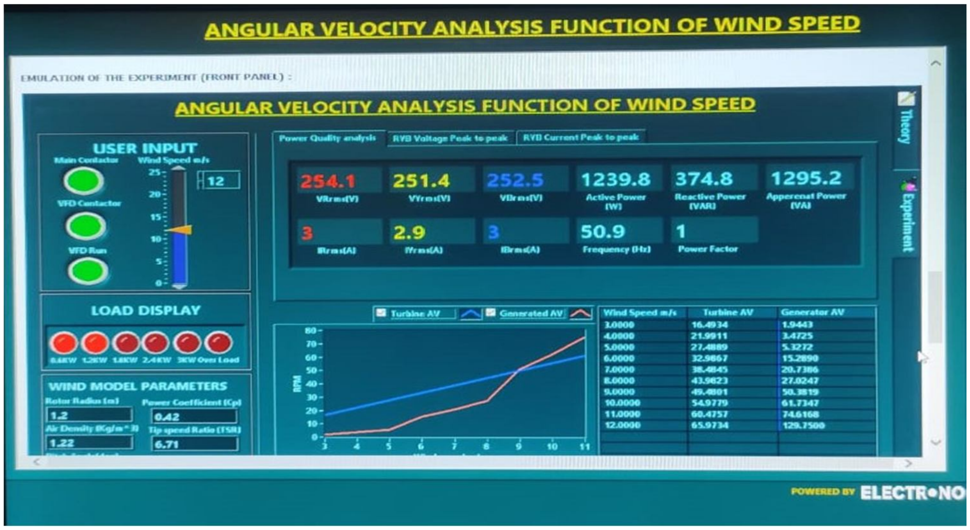

Figure 5: Result of Angular Velocity Analysis Function of Wind Speed

C. Rpm Analysis Function of Wind Speed

Wind turbines transform the kinetic energy of the wind into electricity. The force of the wind on the blades causes them to move. Blades are usually shaped like air foils, using lift to spin the blades faster than the wind. The blades and the hub together are called the rotor. The blades on large utility scale turbines change their pitch to react to wind speed. As the rotor turns, it spins a drive shaft which is connected to a generator. The spinning generator converts mechanical(rotational) energy into the electrical energy. Many large wind turbines often have a gearbox between the rotor and the generator, so that the generator can spin much faster than the blades are spinning. The rotor speed of the wind turbine is allowed to vary up to an upper limit rpm. The variation of rotor speed is divided into three different regions. The first region is called the constant CP region where the rotor speed tracks the wind speed variation. As the wind speed increases, the rotor speed also increases until the rotor speed reaches the upper limit rpm. This maximum rotor speed is determined by the design of the wind turbine components(wind turbine, gearbox, generator, etc). When the rotor speed reaches its limit, the speed should be kept constant regardless of the wind speed. As a result, in this region, the immediate Cp is lower than the intended Cp. As the power grows at a slower rate than the previous region as the wind speed increases. It eventually hits its power limit. The wind turbine must be operated at continuous power once the power limit is achieved (at reduced Cp).When a wind turbine is operated at constant power, it must function in a less efficient mode. To reduce the wind turbine's power production, the Cp must be reduced, which is accomplished by lowering the wind turbine's rpm. More load must be provided to the wind turbine to reduce the rpm. As a result, the generator must absorbs more power, resulting in increased electrical output. Generators on large grid-connected turbines spin at 1200 to 1800 revolutions per minute (RPM).
The function of RPM analysis of wind speed is shown in Table 3. As the wind speed increases, the turbine and generator RPM also increase, which is shown in the Figure 6. The result view is shown in Figure 7.

Table 3: Rpm Analysis Function of Wind speed

Wind Speed(m/s)	Turbine RPM	Generator RPM
3.0	157.5	399.5
5.0	262.5	670.1
7.0	367.5	942.1
9.0	472.5	1210.1
11.0	577.5	1478.1

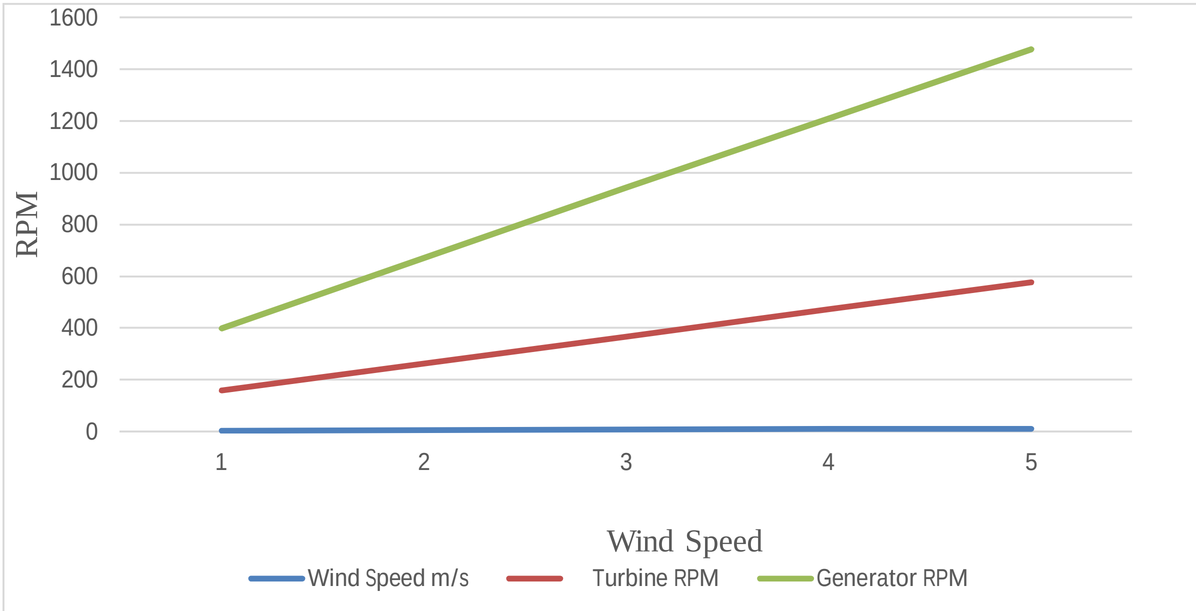

Figure 6: RPM Analysis Function of Wind Speed

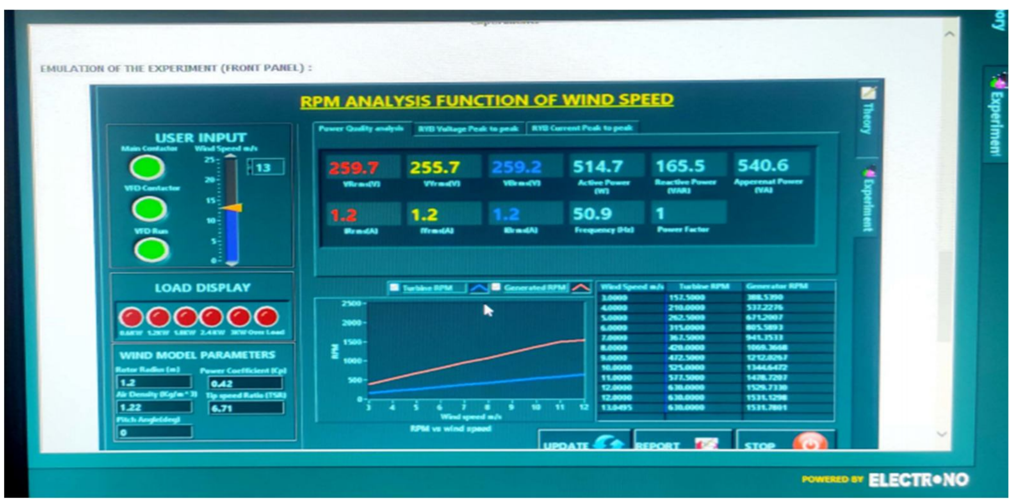

Figure 7: Result of RPM Analysis Function of Wind Speed

D. Torque Analysis Function of Wind Speed

The difference in input and output torque, as well as the stiffness and damping of the shaft, affect the torque translated through the shaft as the wind speed changes. The higher torque spikes on the shaft are caused by rapid fluctuations in wind speed. The rotor inertia, drive-train inertia, stiffness, and damping are all included in the drive train dynamics model. The controller response is another part of shaft torque variation. When the difference between accelerating and deaccelerating torques is large, torque spikes occur. This can happen if the controller tries to increase the load too quickly, or if there is a sudden rise in wind torque due to a gust of wind. If the torque pulsation is to be decreased or damped, the controller gains must be properly tuned. The torque produced at the rotor grows as the rotor speed increases until a point is reached after which the torque gradually drops to zero. As a result, the rotor's mechanical power increases until it reaches a maximum value, then gradually decreases until it approaches zero. The maximum power point is the location where mechanical power is at its highest (MPP).The optimum rotor speed and torque are frequently referred to as the optimum speed and torque, respectively, at the MPP. The turbine torque, generator torque and wind speed are shown in Table 4 represents torque analysis function of wind speed and related graph is shown in the Figure 8 and 9.

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Table 4: Torque Analysis Function of Wind Speed

Wind speed (m/s)	Turbine Torque (Nm)	Generator Torque (Nm)
3.0000	3.8639	204.3465
4.0000	6.8692	156.5778
5.0000	10.7331	124.7636
6.0000	15.4556	52.2092
7.0000	21.0368	45.5052
9.0000	34.7752	24.1145
10.0000	42.9321	21.6670
11.0000	51.9481	19.8957

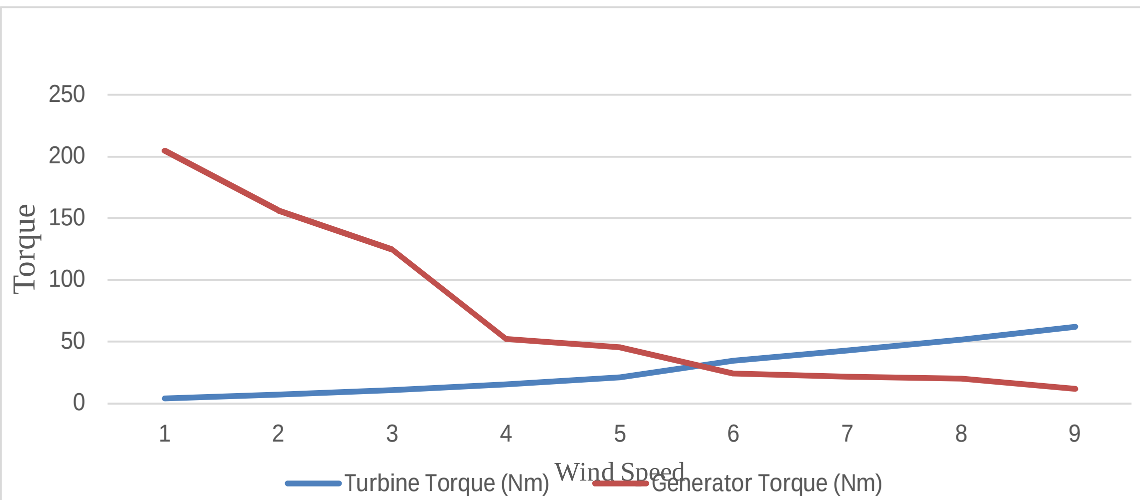

Figure 8 : Analysis of Torque as a Function of Wind Speed

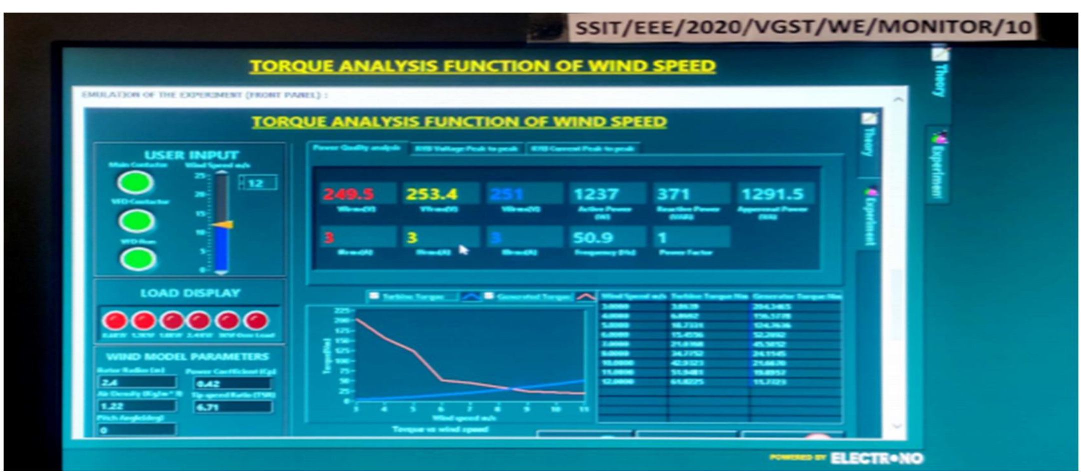

Figure 9 :The Result Analysis of Torque as a Function of Wind Speed

E. Match Grid and Generator Parameters

To match the grid and generator, there are four parameters:

Phase sequence

Voltage magnitude

Frequency

Phase angle

Synchronization is the process of assigning parameters such as voltage, frequency, phase angle, phase sequence and waveform of an alternator (generator) or other source with a sound or operating power system. This is done before reconnecting the generator to the power system. Once one generator is synchronized with the parameters of another generator, alternator or bus line, the system can run smoothly again. Generator synchronization to a power system must be performed carefully to avoid damage to the unit as well as to the power system itself. When synchronizing a generator in a power system, the frequency and voltage of the generator must match closely. To synchronize two electrical systems, both systems must operate at the same frequency and the phase angle between the systems must be zero (both multiphase systems must have the same phase sequence). The Synchroscope measures and displays the frequency difference and phase angle between two power systems. Only when these two quantities are zero is it safe to connect the two systems. Connecting two non-synchronized AC power systems to each other is likely to cause high current flow, which will cause serious damage to any equipment that is not protected by fuses or switches.

Table 5: Match Grid and Generator Parameters

Grid Voltage	Generator Voltage	Grid Frequency	Generator Frequency	Voltage Difference	Phase Angle Difference	Speed
407.2	248.26	51.56	26.93	-38.94	329.9	806
407.2	304.5	51.69	33.06	-25.07	243.9	991
407.3	350.6	51.62	38.03	-14.01	243.6	1140
407.2	396.3	51.69	42.99	-2.96	215.3	1289
407.6	407.6	51.63	44.18	0.01	284.6	1326
407.8	412.2	51.64	45.36	3.25	276.6	1361
407.6	449.6	51.60	48.44	10.2	340.6	1453

IV. ELECTRICAL CHARACTERIZATION TO IMPROVE POWER QUALITY

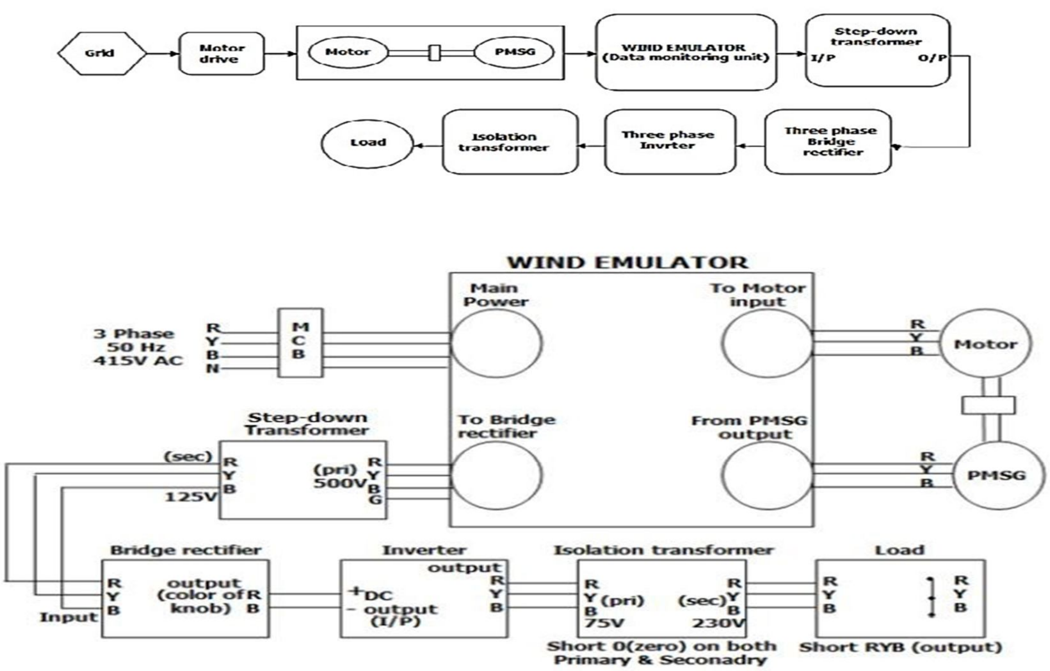

Figure 10: Block Diagram and Connection Diagram for Electrical Characterization to Improve Power Quality

AC and DC integration technologies can be used to connect renewable energy sources to utility networks. Due to its structure, AC integration is a practical and cost-effective solution. However, the quality protection of its power is insufficient. Due to the additional AC / DC voltage conversion, the DC integration approach provides good power quality to the wind simulator, but its power efficiency is lower than the AC integration method. The advantages of both AC and DC integration methods are combined in this project to provide a controlled AC / DC integration system. AC integration is enabled in the proposed approach to provide high integration efficiency when the utility power quality is sufficient. When the power quality of the utility network is insufficient, DC integration is activated to improve the power quality of the wind simulator.

Voltage relaxation and current harmonic distortion were used as detrimental effects on the utility electricity in the model. In terms of voltage and current standards, the results show that the transitions between AC and DC integration modes are reliable.

The design of the block diagram and the connection diagram for the electrical characterization to achieve power quality is shown in Figure 10 and the results are shown in Table 6.

Table 6: Electrical Characterization to Improve Power Quality

Speed	Input frequency	Inverter output voltage	Inverter output current	Frequency
486	4.825	106	0.73	36.20
486	10.307	106	0.727	36.84
489	15.132	106.8	0.733	38.10
644	19.956	142	0.568	36.28
814	25.219	179.7	1.228	36.14
962	29.825	213.3	1.453	36.45
1133	35.087	250.9	1.719	36.29

V. CONCLUSION AND FUTURE SCOPE

Interface of inverter incurrent regulated mode of real and reactive power is included in the proposed study on wind energy conversion system employing battery energy storage for nonlinear load. Battery energy storage improves system stability by providing rapid response and enhancing performance when wind turbine production fluctuates. A passive filter used to minimize harmonics produced by the load and hence power system reliability will improve. It is preferable to replace the induction generator with a doubly fed induction generator for better performance Off-shore wind turbines will be used in the future due to their advantages of providing high power

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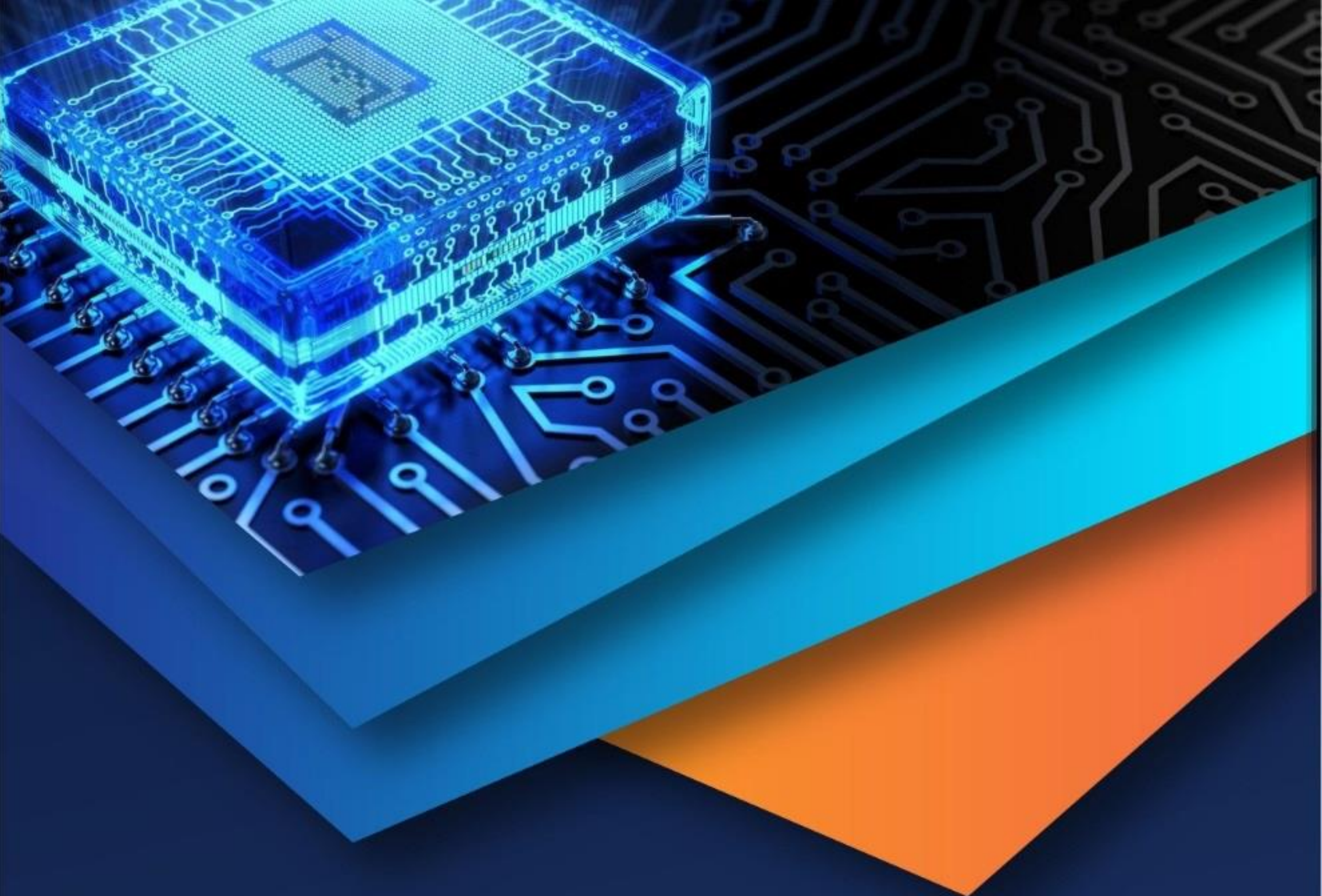

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