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ASSESSMENT OF POWER QUALITY ISSUES IN GRID CONNECTED RENEWABLE SOURCES

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Abstract

The production of renewable energy from sources including hydroelectric dams, wind turbines, and photovoltaic (PV) systems has significantly increased in recent years. This study focuses on specific types of renewable energy, such wind energy, as well as the function of smart grids in addressing problems like dependable and efficient electricity distribution and the integration of renewable sources. In order to solve power quality issues like harmonics in the grid current by supplying more potent reactive power to the grid, a FACTS device called a STATCOM is installed at a point of common coupling for grid-connected wind turbines in this article.

Keywords: PV Cell, STATCOM, Wind Turbine, Power Quality.

INTRODUCTION

Traditional energy sources like fossil fuels or nuclear power are under more environmental pressure as the world's need for electricity rises. This is a direct result of global warming, which is made worse by energy emissions from the burning of fossil fuels. Fossil fuel consumption accounted for more than 89% of the world's main energy consumption in 2023. It is anticipated that use of renewable energy will rise as fossil fuel sources decline. Wind energy is captured by the wind turbine and transformed into generator torque. The torque is transformed into energy by the generator and sent into the grid. 1,500 tonnes of carbon dioxide, 6.5 tonnes of sulphur dioxide, and 3.2 tonnes of nitrogen oxides can be eliminated annually by a 1 MW wind farm. [1]. PV generation is a technique that turns solar energy into electrical energy in photovoltaic (PV) cells employing the solar cells. These days, solar power generation is becoming more and more popular as a renewable energy source.

While large-scale power generation is connected to transmission systems, small-scale distributed power generation is connected to distribution networks. There are several difficulties with these systems' direct integration. As a result, wind energy has seen significant global investment. Nevertheless, obtaining high-quality power can be challenging since changes in wind speed have an impact on the voltage and active power output of the electric machine connected to the wind turbine. Solar penetration has an effect on the utility grid's transmission and distribution systems, voltage profile, and frequency responsiveness [2].

Table 1. Grid-connected wind turbine's transmittable electricity

Voltage Ratings	**Range**	**Size**	**Power Ratings**
LV	Less than 600V	Small to medium-sized wind turbines	= 300kW
MV	600V -35KV	Medium to large wind turbines	10-40 MW
HV	35 kV -132 KV	Medium to large on shore wind forms	= 100MW
EHV	132 KV and above	Large offshore wind forms	More than 0.5GW

POWER QUALITY ISSUES IN GRID CONNECTED WIND ENERGY SYSTEMS

The grid's direct integration with wind and solar power generation technologies presents a number of challenges. Grid-tie Integration Utilising inverters, renewable energy sources are connected to the grid. An inverter is used to draw energy from the grid when renewable energy sources are insufficient. Additionally, as more electricity is produced, it will be needed for energy delivery. Connecting to the grid, using renewable energy, and It simply takes 100 milliseconds to break the connection. In grid systems that are connected to wind turbines, it provides mechanical and electrical frequency isolation [3].

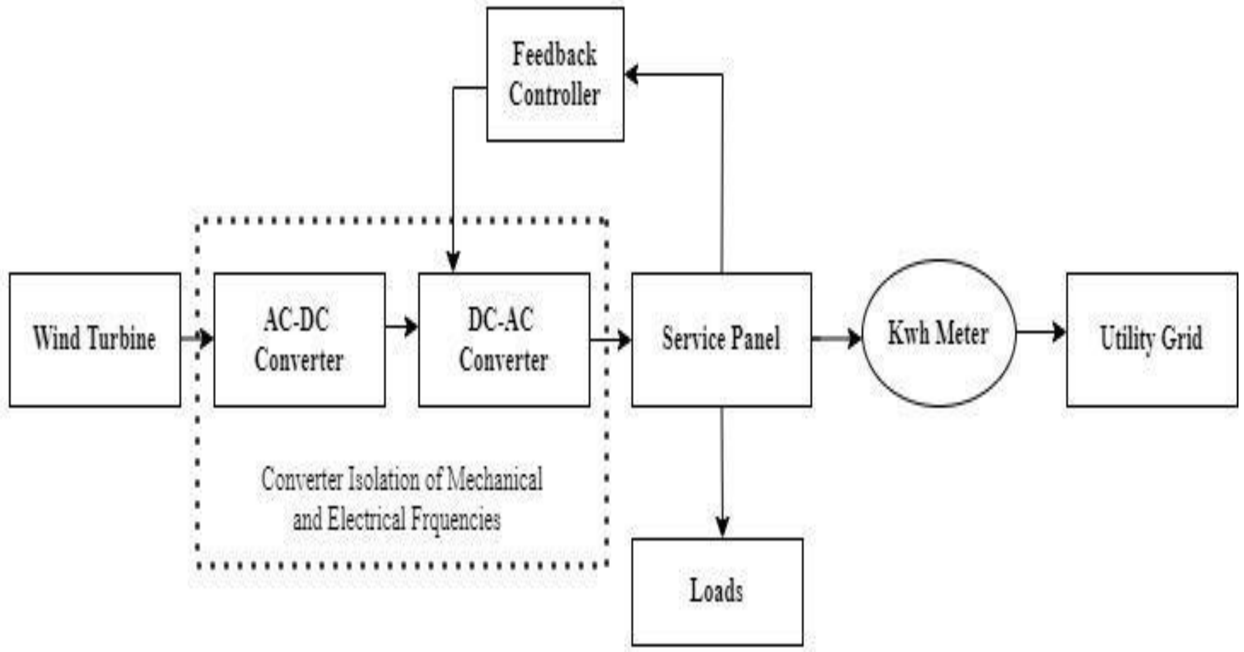


Fig.1. Block Diagram for Grid connected Wind Turbine

HARMONICS

Current or voltage frequencies with integer multiples of the fundamental power frequency are called harmonics. All electrical devices and generators create harmonics, and when those harmonics are present in large enough quantities (as they are, for instance, when computers and compact fluorescent lights are utilised), they can lead to interference and a number of power quality problems. Due to their network dispersion, the majority of grid-connected inverters for DG applications produce relatively little harmonic current, making harmonic problems unlikely even at high penetration levels. The most common type of inverter, the current-source inverter, cannot offer the harmonic support the grid needs. However, there are numerous harmonic compensators that are probably less expensive and voltage-source inverters can, albeit at a cost to energy.

It would be easier to purchase voltage or current source inverters as needed with the help of labelling that clearly identifies the kind of inverter (voltage or current source), as well as financial incentives for minimising energy losses if voltage source inverters are installed. Since PV inverters disconnect from the grid when there isn't enough sunshine to counteract switching losses, harmonic assistance isn't offered all night long unless otherwise stated [4].

FREQUENCY AND VOLTAGE FLUCTUATIONS

Frequency and voltage fluctuations are categorized as follows

i. Unbalanced voltage: Voltage imbalance in a three-phase system happens when the phase difference is not exactly 120° or when each phase voltage has a variable amplitude. Excessive installation of single phase systems on a single phase can lead to networks that are dangerously unbalanced, damaging controllers, transformers, DG, motors, and power electronic equipment. The total size of all linked systems to each phase should be as equal as possible with high PV penetrations. A balanced three phase output is typically required for all systems with a power output of between 5 and 10 kW [5-6] .
ii. Voltage fluctuations derived from the grid: Inverters are frequently designed to operate in "grid voltage

tracked" mode, disconnecting DGs when grid voltage exceeds predetermined criteria, to ensure they produce adequate power quality and prevent unintended islanding. When multiple DG systems or large DG systems are connected to a single feeder and are automatically removed due to an out-of-range grid voltage, it might be inconvenient for other generators on the grid to be required to provide additional power. Raising the voltage tolerance and, if possible, incorporating Low Voltage Drive Through (LVRT) technology into the UPS design can stop this. When the grid voltage is low, the inverters are allowed to operate for a limited time under the LVRT; but, if the grid voltage drops below a specific threshold, they will instantly disconnect. Inverters can also be configured to operate in "voltage regulation" mode, in which case they try to alter the grid voltage. Voltage regulating converters help to raise grid voltage by injecting reactive power during voltage sags and withdrawing reactive power during voltage surges. The architecture of the connection standard must consequently include converters in order to provide the necessary reactive power without interfering with the islanding detection system. Utility companies could also demand training on how to combine these converters with other voltage regulation solutions like SVC or STATCOMS. [7-8]

iii. Power flow reversal and voltage rise: In conventional centralized power networks, power only moves in one way from the power plant to the transmission, distribution, and load networks. Voltage is often given at a level that is 5–10% greater than the nominal end-use voltage in order to allow for line losses. In order to correct for voltage drop and maintain the voltage across the line within the predetermined range, voltage regulators are also employed [9].

iv. Correction of the power factor: Increased line losses brought on by a poor power factor make voltage rectification more challenging. A grid with a low power factor hinders both line losses and voltage regulation. Voltage-regulating inverters generate current that is out of phase with the grid voltage and enable power factor management, as opposed to voltage-following inverters, which have a power factor of one. This could be a simple fixed power factor or one that is automatically controlled by the volt-age of the power supply.

There are several factors to take into account while altering power factor with inverters. To allow reactive power injection and deliver the most active power, the inverter size must be increased. Energy costs associated with reactive power assistance, an assessment of VAr compensation, and SVCs or STATCOMS are probably more cost-effective for simple reactive power support due to their lower energy losses, even though inverter VAr compensation is endlessly variable and has very fast response times. An inverter VAr compensator may be necessary when severe load transients, such as motor starts, are generating quick voltage shifts.

However, sites off the grid have considerably higher system impedances at the point of connection, making VAr compensation less effective for voltage management. This is true even if the majority of networks can successfully manage voltage using this kind of reactive power compensation. Real power injection is more effective at controlling voltage in these circumstances.

A sort of centralised control was also required to maintain optimal network operation at significant PV penetrations, according to studies looking at the usage of inverters to control network voltage. Feeder voltage limitations may also restrict the amount of reactive power that inverters may inject, making coordinated operation of inverters and utility equipment as well as additional utility equipment necessary.

Power Quality issues in grid connected wind Energy systems

The rotor, gearbox, and generator are the three primary components of a Wind Turbine that produce power. The converter system's driving element's rotor transforms fluctuating wind energy into mechanical energy. Fig. 2 displays the block diagram of the grid-connected wind system. A circuit breaker that permits total disconnection of the wind farm or the wind farm must be present on an isolated wind farm or the common connection point (PCC) between the wind farm and the grid. Typically, a substation with a meter installed for billing purposes and close to the medium voltage system is where this circuit breaker can be found.

Usually, it has built-in voltage and current converters. A radial feed or a ring feed can be used to connect to the medium voltage grid, depending on the special circumstances of the current power supply system.

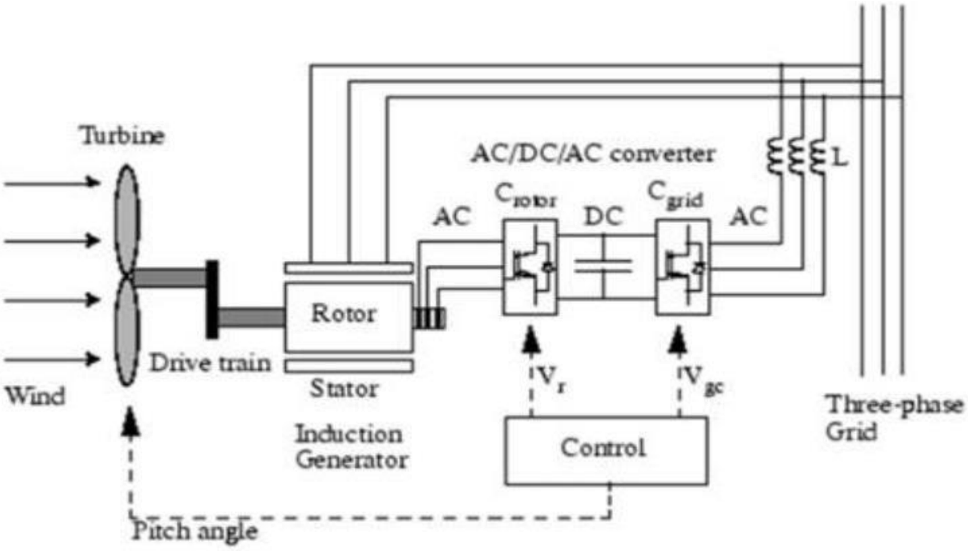


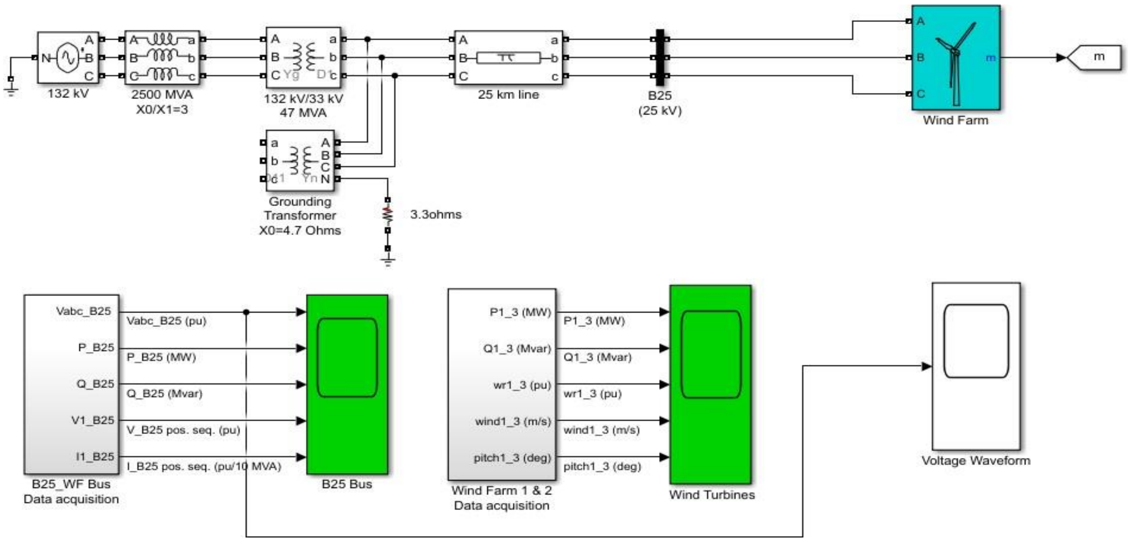
Fig.2. Wind turbine schematic with grid connection

SIMULATED SYSTEM

The wind farm equipped with Power Factor Correction (PFC) without fault and STATCOM was simulated through MATLAB SIMULINK toolbox.

A 9 MW wind farm made up of either 6 1.5 MW wind turbines or 3 1.5 MW wind turbine pairs is shown in Figures 3 and 4. On the squirrel cage induction generators with set speeds, pitch angle modification is possible. The farm transmits electricity to a 120 kV network via a 25-kilometer transmission wire. The system features are shown in tables 1 and 2. For each wind turbine, a 400 KVar PFC capacitor is connected to the generator's terminal to partially counteract the reactive power absorbed by the squirrel cage induction generator.

PFC without fault



PFC with fault

Fig 3. MATLAB Model of Grid connected wind turbine with only PFC and without fault

The setup depicted in Figure 3 and Figure 4 includes a 9 MW wind farm made up of either 6 1.5 MW wind turbines or 3 1.5 MW wind turbine pairs. Pitch angle adjustment is available on the fixed speed squirrel cage induction generators. The farm uses a 25-kilometer transmission cable to send electricity to a 120 kV network. The tables 1 and 2 display the system characteristics. A 400 KVar PFC capacitor is attached to the generator's terminal for each wind turbine in order to partially offset the reactive power absorbed by the squirrel cage induction generator.

Table 2. Model base values

Vbase	120 KV
Pbase	9 MW
Fbase	50 Hz

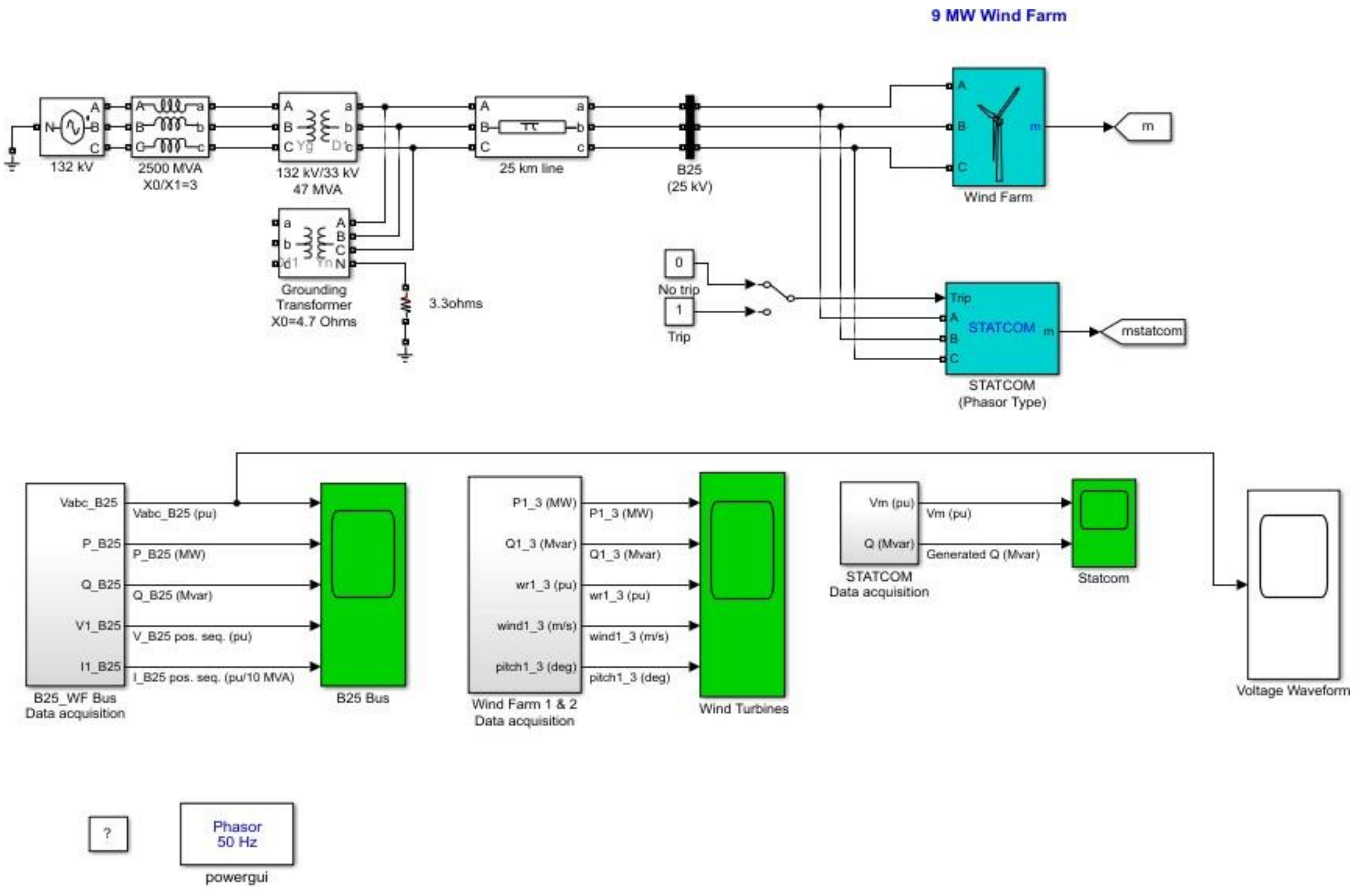


Figure 4. MATLAB Model of Grid connected wind turbine with STATCOM

Table 3. 9 MW Induction Wind turbine Model Parameters

Stator resistance (R_s)	0.004843 pu
Rotor resistance (R_r)	0.004377 pu
Magnetizing inductance (L_m)	6.77 pu
Reactive power of STATCOM ($Q_{STATCOM}$)	3 Mvar

STATCOM has connected to 25kv bus that supplies the rest of the needful reactive power. The capacity of each STATCOM is three MVar. The system equipped by STATCOM is shown in Figure 4. The power network comprises a 120kv generator with 50 HZ frequency. The generator has a 1 1 X R =10 ratio and short circuit ratio of 2500 MVA, that connects via a 120/25 kV U / D 47 MVA transformer. It is connected to a 25kv bus via a 25 km transmission line.

Simulation Results of Wind System

In the beginning, system trials with only PFC and no defect were carried out, and the outcomes are displayed in figure 6. The simulation lasts for 20 seconds.

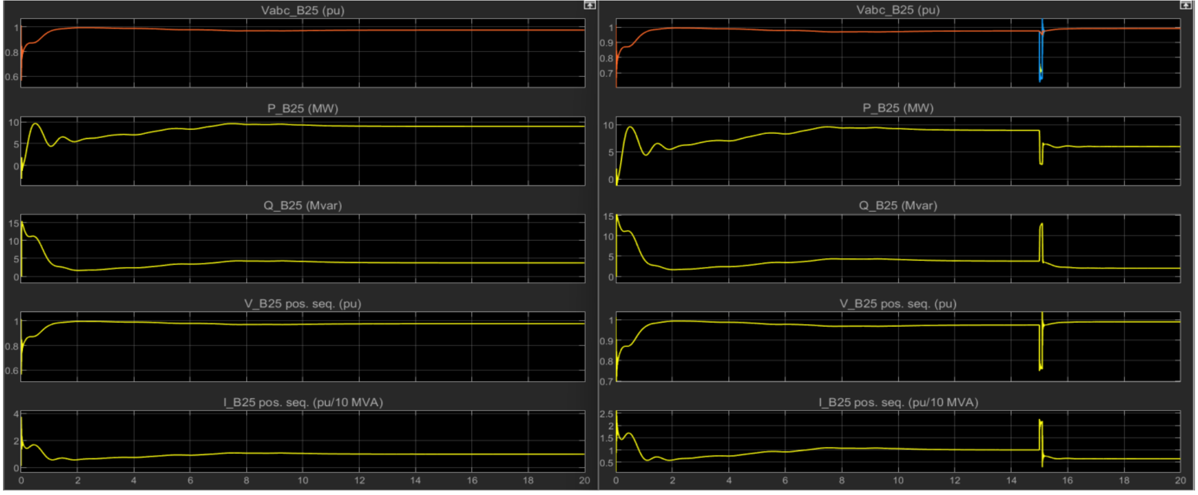


Fig 5(a). Voltage, active and reactive power of the bus at 25KV with PFC & without fault

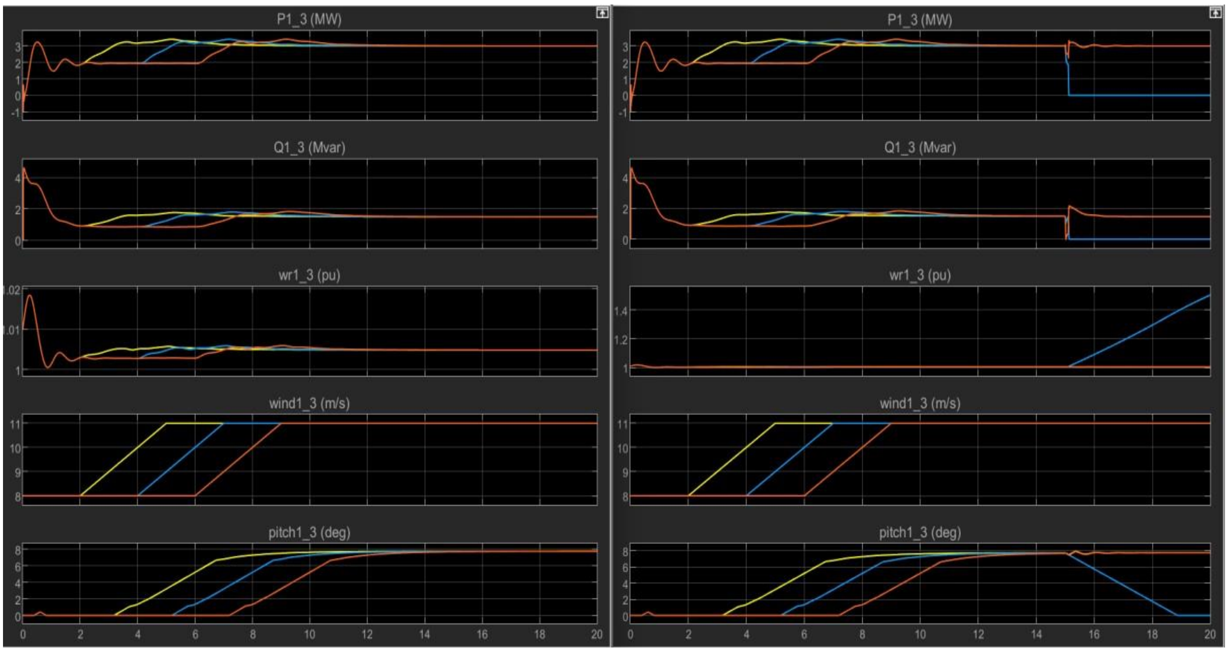


Fig 5 (b). Voltage, active and reactive power & rotor speed of 3 pairs of wind turbine with PFC & without fault

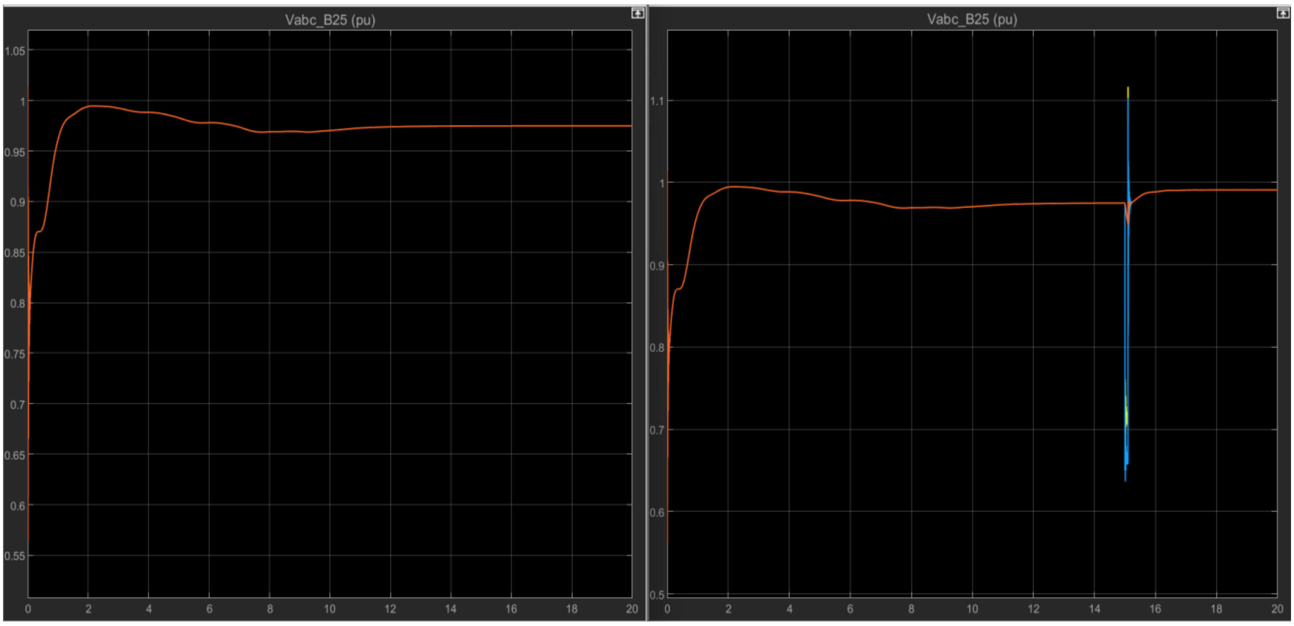


Figure 5(c). Voltage waveform of MATLAB Model with PFC and without fault

Figure 5 shows that the first wind turbine, which is shown in Figure (5-b), was unable to absorb enough reactive power due to a 7% voltage decrease in bus 25 kV at t = 14.43 seconds. As a result, this turbine lost stability, which led to a rise in rotor speed as shown in Figure (5-b). The first wind turbine is then disconnected from the network by the safety mechanism, and both its active and reactive power are zero as shown in Figure (5-a). The following scenario is run with a fault that is cleared after 0.1 seconds and only PFC. The outcomes are shown in Fig. 5. On t=15 and after 0.1, the second wind turbine's terminal is regarded as having a line-to-line to ground failure. Figure 5 shows that the first wind turbine is blocked at time t = 14.43 seconds due to a weak electrical torque. Following the incidence of a line-to-line to ground fault at time t = 15 seconds, which is resolved at time t = 15.1 seconds, the second wind turbine will start to accelerate. (5-b). Due to insufficient reactive power and electrical torque in the FSIG, the second turbine is tripped by the safety system as shown in Figure (5-a) and Figure (7-b). Therefore, providing active and reactive power to the 25 kV bus is the third wind turbine's responsibility. Figure (5-b) illustrates what happens after a failure occurs at time t = 15 seconds. A 400kvar PFC capacitor is used to introduce reactive power into the 25kv bus. After fault clearance on t = 15.1 seconds the reactive power injection decreases.

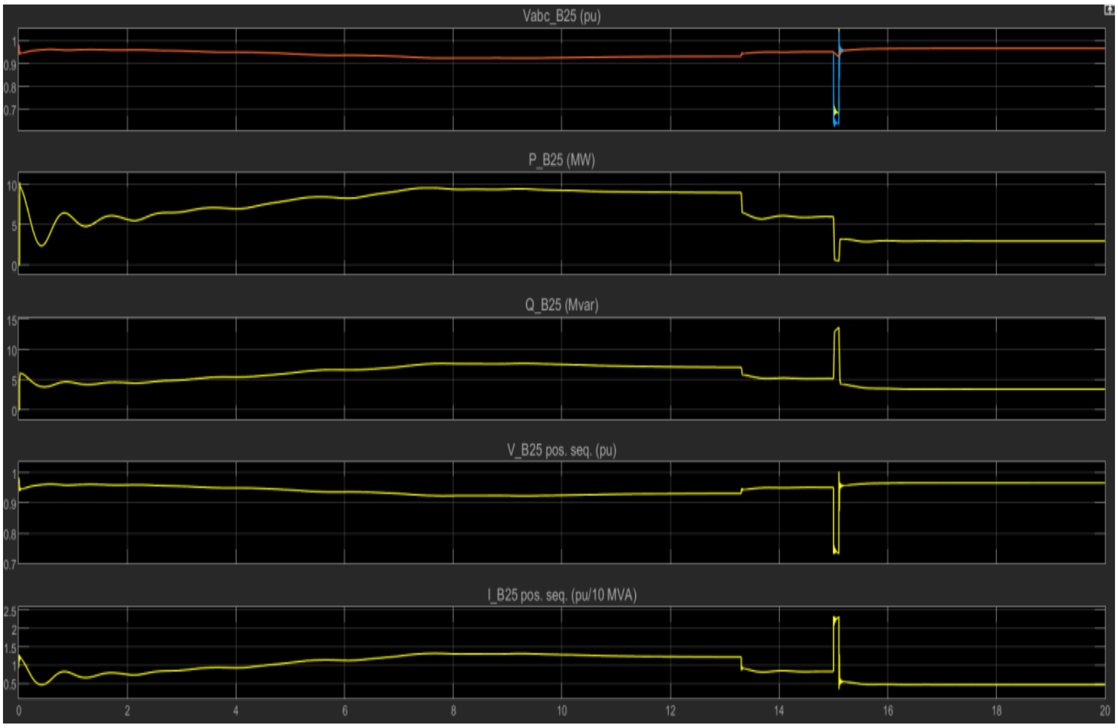


Figure 6(a). Voltage, active and reactive power of the bus at 25kv with additional MVar STATCOM

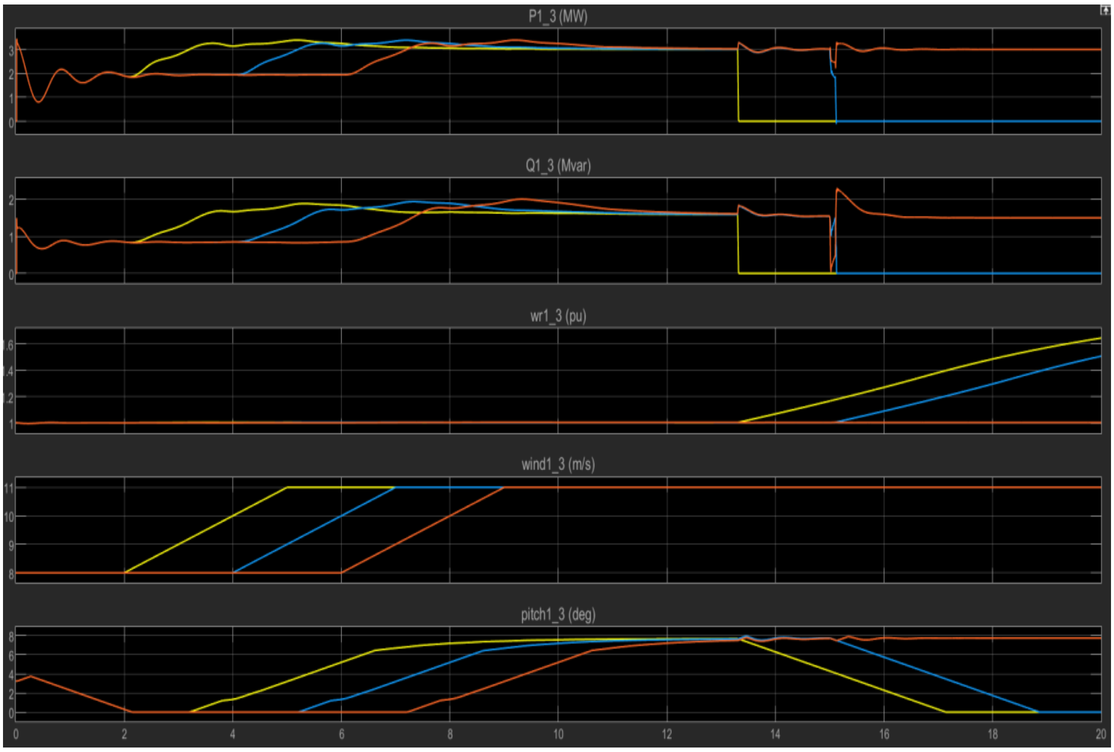


Figure 6(b). Active, reactive power, and rotor speed of three pairs of wind turbine MATLAB Model with additional MVar STATCOM

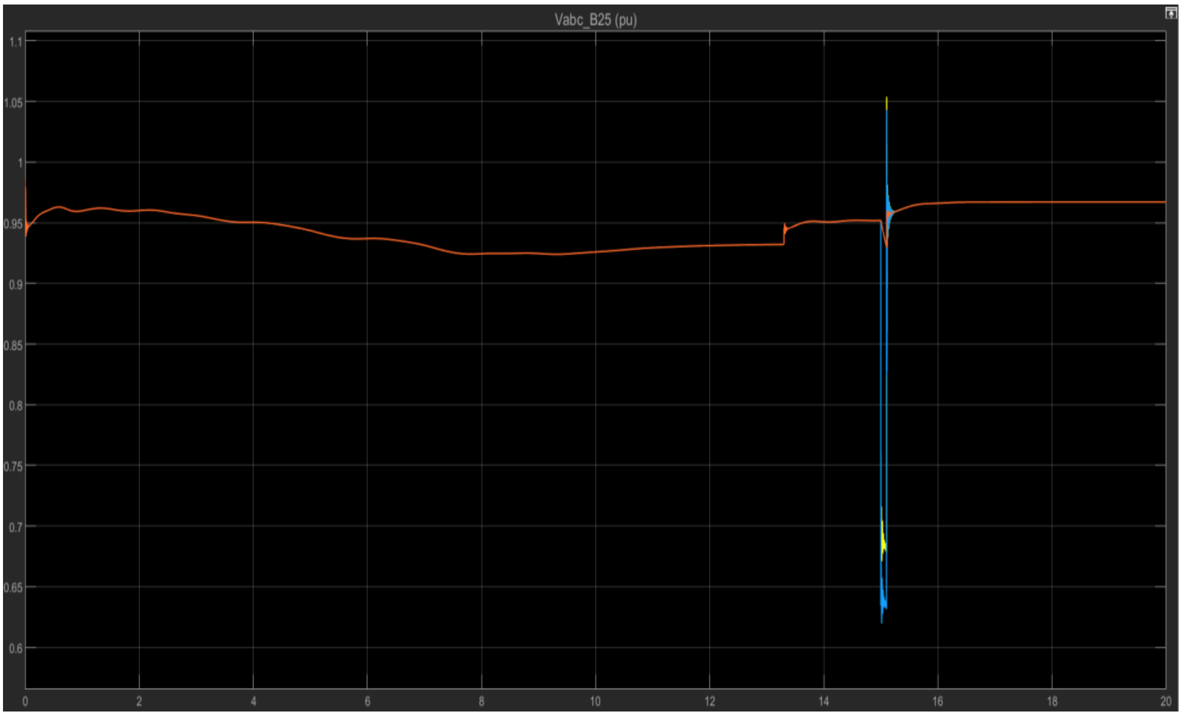


Figure 6 (c). Voltage waveform of MATLAB Model with additional MVar STATCOM

Figure 6 shows the simulation findings for the same network configuration with an additional 3 MVar STATCOM. The presence of STATCOM, as shown in Figure (6-a) and Figure (6-b), allows the first wind turbine, which was removed by the protection system on t=14.43 second in the previous simulation, to maintain its stability and generate active and reactive power. (6-b). Due to STATCOM's limited capability, the second wind turbine cannot continue operating.

Provide the required reactive electricity, and it trips. Figure (6-a, b), and (6-c) show that the active power of a 25 kV bus decreases after a fault occurs on time interval (15), and this drop lasts until the fault is removed on time interval (15).

CONCLUSION

The paper investigates the role of FACTS devices like STATCOM in improving system efficiency. Power swing dampening, voltage regulation, enhanced power transfer, and Hiefly as a supplier of controllable reactive power are improvement variables that help to hasten voltage recovery once a failure occurs. However, the active power reduction with STATCOM is larger than with PFC alone. However, network voltage has no impact on the maximal reactive current of STATCOM; instead, thyristor capability is the only limit. It can be observed that the active power of the bus increases after t = 15.1 sec. until, after numerous swings, it reaches its steady quantity (6MW). The second wind turbine was not working due to an increase in STATCOM's capacity from 3MVar to 3.5 Mvar.

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