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POWER QUALITY CONTROL OF WIND POWER PLANTS BY USING FACTS DEVICE

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Abstract

As the energy cost from conventional power plants increases due to the increase in Fossil Fuels, Renewable energy has become an essential alternative energy source to reduce the overall cost of electrical energy and meet the current demand. With the transformation of power grids due to the significant penetration of RES based on power electronics energy converters such as wind energy and solar power (PV), the control and operation of linked networks have become demanding to preserve their sustainability and efficiency. The power system faces various new stability difficulties due to the dynamic behavior of renewable energy in the converter interface sources being different from that of traditional power generation. Wind energy is one of the most developing Renewable energies, which is now a day's utilized in most countries around the globe to satisfy the present demand. As the wind velocity never remains constant, the wind turbine's output constantly changes, resulting in Flickers, voltage sags, and harmonics, which impact the power quality on a vast scale. The poor power quality of the wind power plant is the fundamental limitation in the growth of wind energy. In this view, a synchronous static compensator (STATCOM), a flexible alternating current transmission system (FACTS) shunt coupled, is considered an essential solution for preserving the stability of the power grid. This work proposes the (STATCOM) influence of static and transient circumstances on wind turbines. It examines several STATCOM control models based on adaptive, conventional, predictive, robust, and coordinated control and soft computing methodologies. MATLAB/SIMULINK is used in the power system block to simulate the power grid coupled with a wind power generation scheme to improve the power quality. Based on the data collected

Keywords: **STATCOM, Power quality, dynamic behavior, Renewable Energy, Wind energy, FACTS Devices.**

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INTRODUCTION

Due to urbanization and social industrialization, traditional energy sources can no longer supply demand. Hence people are turning to renewable energy sources (RES). Traditional pollution causes have also pushed power firms to invest in green energy, rather than fossil fuels, to reduce pollution. There has been an increase in renewable energy sources in today's energy system, as evidenced by (Figure 1). [1] Renewable energy sources that rely on power electronic converters, such as wind and solar, are more popular, thanks to recent advancements in power electronic devices. These resources are considered an essential part of the solution to meet the growing need for sustainable energy.

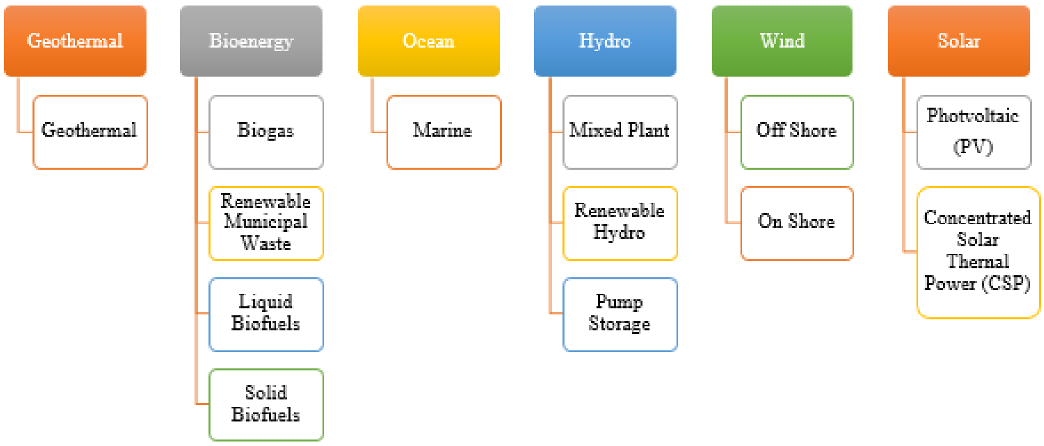

Figure 1 RES Classification Error! Reference source not found.

The cost of RESs electricity generation has decreased significantly over the past decade (2010-2019). Onshore and offshore wind energy costs have dropped by 82 %; solar photovoltaic (CSP), 47 %; concentrated solar energy (CSP), 39 %; and 29 %, correspondingly. The energy sector's solar and wind energy capacity has grown dramatically due to the sudden price drop. When comparing hydropower (without a pumping tank) and other renewable sources, Figure 2 shows an apparent rise in the capacity of solar (PV) and wind energy (onshore or offshore). [1]–[3]

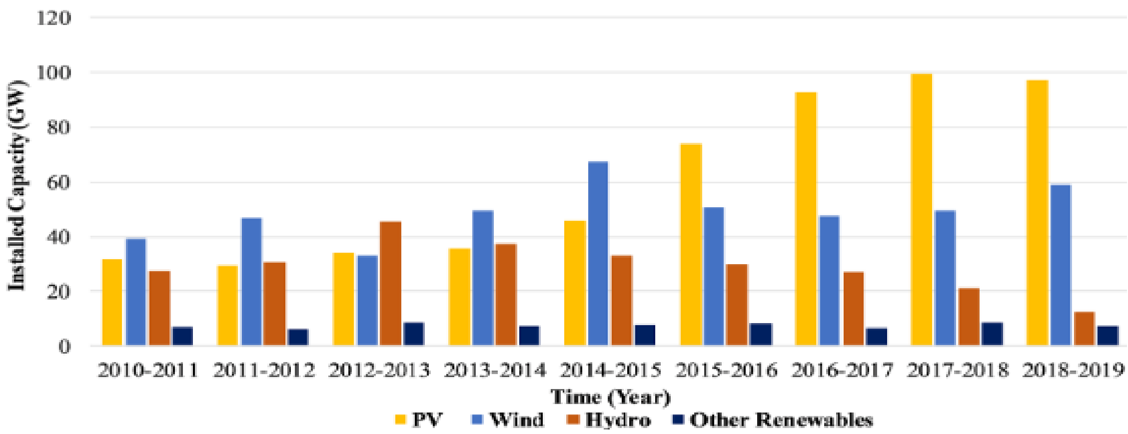

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Figure 2 2020 Statistic of Renewable Energy Capacity Error! Reference source not found.

Hydropower has always been the largest renewable energy source, but hydropower has remained relatively high in recent years. Therefore, photovoltaic and wind energy are almost the same in hydropower capacity, as shown in Figure 3. Although these figures are fantastic in fulfilling energy demand, the transmission of these numbers could be better, especially when they are modern solar systems and wind turbines. Low short-circuit resistance and low inertia and control interaction in specific converter interface sources have led to stability issues.00Asymptomatic bacteriuria (ASB):

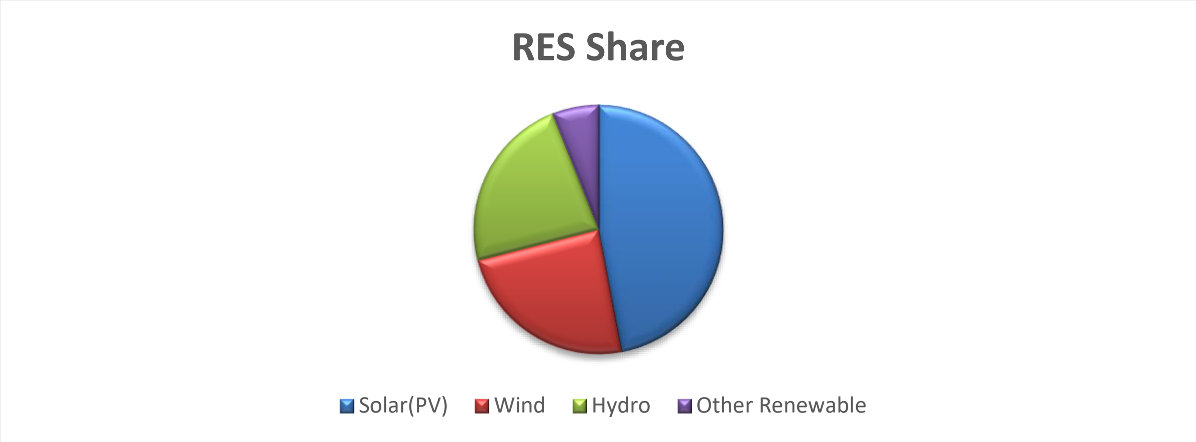

Figure 3 2020 Statistic of Renewable Energy Capacity Error! Reference source not found.

Since power electronics have advanced, the development of FACTS devices has occurred. 0-0Electronic components are regarded as the most critical technology for increasing wind turbines' static and dynamic performance. 0-0 Power supply systems increasingly rely on STATCOMs because of their dynamic reactive power compensation, rapid fault detection, and constant output response. Compared to static reactive power compensators, they are more effective in supplying the necessary reactive current at lower voltages (SVCS). [4]–[8]

They are more compact than SVCs and, when properly designed, can handle transient overloading due to the lower number of passive components they contain. A capacitor/reactor or tap changer is an excellent choice for steady-state applications due to its long response time (from a few seconds to several minutes). 00However, STATCOM devices offer lower power losses and less noise than synchronous condensers, making them more cost-effective and ecologically benign. Some of the additional benefits include a reduction in flickering voltage and harmonics.

Power factor correction is typical practice in the wind and solar farms in China using STATCOMs of small and medium capacity. As a result, STATCOMs in the wind and solar integrated power systems are now being studied more thoroughly. An illustration of this is shown in Table 1, which displays the global distribution of STATCOM implementations. 00

This paper's control and operation procedures show STATCOMs to stabilize wind-invading power frameworks. The paper design is discussed in detail in the next section. The results of wind's integration into traditional power grids and the resulting strength challenges are discussed in Segment 3, the literature survey. Section 4 talks about the power quality issues. Section 5 describes the STATCOM control methodologies for improving voltage strength and reverberation dependability. In this part, various cases execution through MATLAB/Simulink. Section 6 will cover concluding comments.

COUNTRY	REGION	CAPACITY(MAR)	COMMISSION YEAR
CHINA	Shanghai	±50	2006
	Guangdong (04 STATCOMs)	±200 each	2011 and 2013
	Yunnan (04 STATCOMs)	±100 each	2016
	Mongolia	±20	2014
UK	East Claydon	0/+225	2000
CHILE	Cerro Navia	-65/+140	2011
USA	Alabama	0/+220	2016
	Mobile STATCOM	±50	2018
INDIA	Aurangabad (02 STATCOM)	±150 each	2018
	Rourkela (02 STATCOM)	±150 each	2018
AUSTRALIA	Queensland (04 STATCOM)	±100 each	2011

Table 1: STATCOM Worldwide Implementation. [27]

METHODOLOGY

This paper addresses the issues and their mitigation as incurred in the wind power plant network of Jhampir, Thatta, Sindh, Pakistan, a developing electrical energy source. This case study of a wind power station network is discussed to avoid the dire consequences of the power plant due to variations in wind velocity. The power-driven output of the wind turbine fluctuates, which may cause a severe issues on power quality such as voltage variation, flickers, and resonance variation. Due to the oscillations, the overall power quality of the wind farm will be poor. Therefore, the general aim of this paper is to implement STATCOM to decrease the above variables that impact the quality of wind power energy and to observe the effect of STATCOM on the various parameters of wind power energy. MATLAB/Simulink model is developed for several cases: Establishment of a wind farm steady-state and dynamic model. Observe the voltage at the bus without STATCOM, then the voltage at the bus with STATCOM in a steady state.

LITERATURE REVIEW

Wind energy has developed enormously. In 1999, the global installed capacity exceeded 10,000 megawatts; this year, the global new installed capacity exceeded the core capacity. The worldwide perspective of wind energy looks to be reasonably good. The United States Department of Energy announced the "Wind Power America" plan in 1999, with a target of 80,000 megawatts of wind energy by 2020. Wind energy accounts for roughly 5 percent of overall electricity demand in the United States. According to the European Commission's white paper "Energy for Future Renewable Energy," released at the end of 1997, 40,000 megawatts of wind energy will be available by 2010. Germany installed roughly 4,500 megawatts of wind power at the end of 1999, an increase of 1,500 megawatts this year. If it turns out that 2000 was Denmark's average wind year, wind energy should fulfill 13 percent of the country's energy demands. According to Denmark's energy strategy, wind power should provide 15-

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16% of the country's electricity. By 2030, renewable energy is expected to account for 50% of Denmark's electricity consumption, with 4,000 megawatts of offshore wind power. Due to the increased installed capacity, wind energy is one of the fastest-growing sectors. According to new data from the Danish Wind Turbine Manufacturers Associations, output has expanded sixfold in the previous five years, equating to an annual growth rate of 44%. 0

- Finally, wind power has evolved into a competitive renewable energy generation technology during the last 20 years.
- In several nations, wind power will generate double-digit percentages. There's no explanation why wind energy can't become as vital as nuclear power in the world's power production.

PAKISTAN'S WIND ENERGY

The lack of energy is a significant problem in Pakistan. Renewable energy sources are becoming increasingly popular as a short-term solution to present difficulties in the wake of this. In 2005, Pakistan's Meteorological Department and the Alternative Energy Development Board (AEDB) discovered wind speeds of around 7.3 meters per second (m/s). Jhimpir is part of Pakistan's "Gharo-Keti Bandar wind corridor," which has the potential to produce up to 50,000 MW of power.

The Jhimpir Area Development Board has approved twelve wind power projects in the (AEDB). 106 Megawatts (MW) of wind power are expected to be generated in Jhimpir, Sindh's Thatta District village. An explosion occurred at Pakistan's Fauji Fertilizer Company Energy Limited (FFCEL) on December 24 will begin supplying 49.5 MW of wind power to the national grid at the cost of $143 million.0

POWER QUALITY ISSUES

After the development in the renewable energy field, the world is moving towards renewable sources to generate electricity. Oil prices continuously rise daily, and reserves are reducing continuously; therefore, engineers are moving to renewable energy as a cheap and natural energy source. Wind energy is one of the renewable energy sources. Since ancient times, the wind turbine has been used for industrial and domestic purposes but on a small scale. As wind energy becomes more commercialized and substantial wind farms are built, the challenge of power transmission from the wind farm to the surrounding grid arises. Wind power's integration into a grid-connected system impacts power quality.00 The influence on the current quality leads to voltage, current, and frequency deviations from their nominal values, which may lead to equipment failure or malfunction. An ideal electrical system sinusoidal waveform has a clean and continuous voltage and current profile with a constant fundamental frequency. Because changes in the wind create changes in the mechanical torque, the power and output of the wind turbine generator fluctuate significantly. Voltage sags, swells, flickers, and harmonics are pumped into the system together with wind power.00 These voltage sags, swells, flickers, and harmonics disrupt the voltage profile, lowering the quality of wind energy.

Harmonic production, voltage sag, voltage swell, overcurrent, and flickering all degrade the system's power quality. For better power quality, start by lowering these variables. Following is a list of the primary determinants of power quality:

1. Voltage swells
2. Voltage sags
3. Transient
4. Inrush
5. Flickering
6. Overcurrent

It is pretty challenging to determine whether the problem with power quality stems from the user or the provider. The power quality is a concern affecting both suppliers and end users. Listed below are the various types of power outages that may occur. 00

A. Power outage

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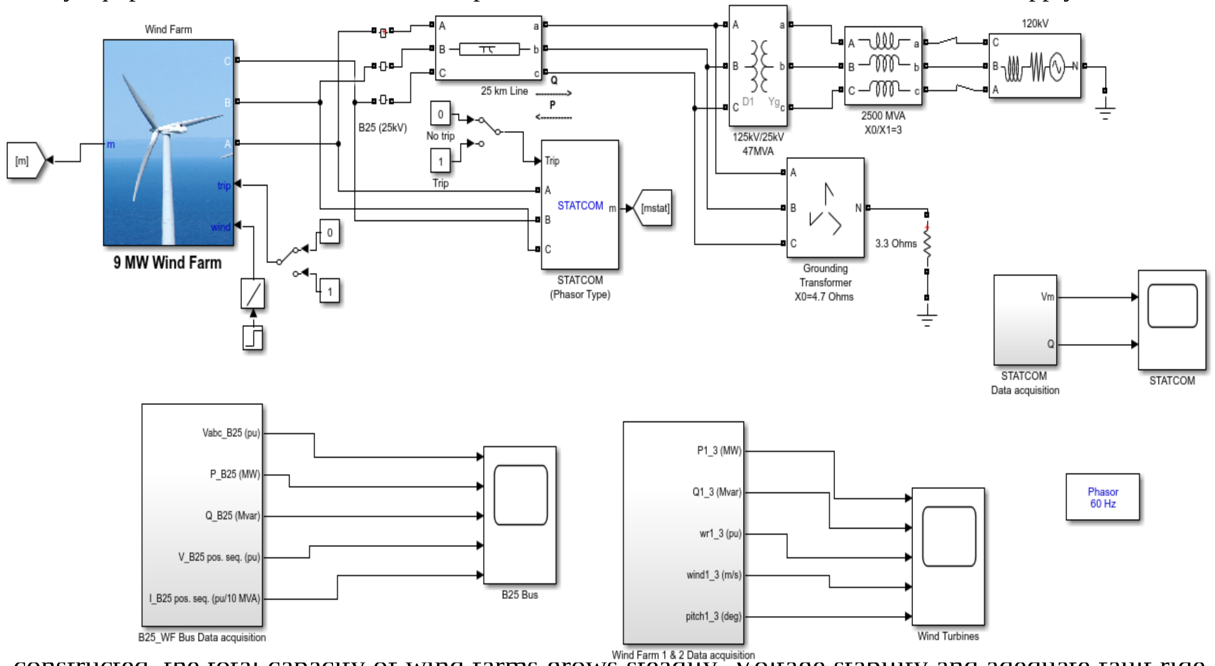
A power outage is a technical term for the complete cessation of supply. The ice storms, lightning, wind, and utility equipment failure contributed to the power loss. The result is a total breakdown of the supply chain.0



constructed, the total capacity of wind farms grows steadily. Voltage stability and adequate fault ride-through capability are both required for greater penetration. When the voltage fluctuates, the wind turbine should still be able to run. The dynamic stability of wind farms is a significant concern when interconnected to the grid. The voltage may become unstable when a power system can't fulfill reactive power demand during power outages and heavy loads. An average wind farm is located in a large area with many wind turbines that create varying power depending on the wind conditions. For example, STATCOM and Unified Power Flow Controller UPFCs are frequently used in power systems because of their ability to flexibly regulate power flow. Wind farms can benefit significantly from using STATCOM to keep bus bar voltage constant because of its ability to supply or absorb reactive power. Our system uses a STATCOM to dampen power oscillations, adjust wind turbine voltage dynamically, and control power flow dynamically in transmission lines. Static and transient interruptions are no match for the STATCOM devices, according to the results of the simulations.

Computational Model

When connected to a 120 kV grid by a 25 km long 25 kV feeder, the farm's six 1.5 MW wind turbines at a voltage of 120 kV create electricity Figure 4 depicts the study system simulated in MATLAB. This paper evaluated the impacts of wind turbine rotor speed, reactive power, active power, and voltage on the assessed system on the 25-kV bus with and without STATCOM.

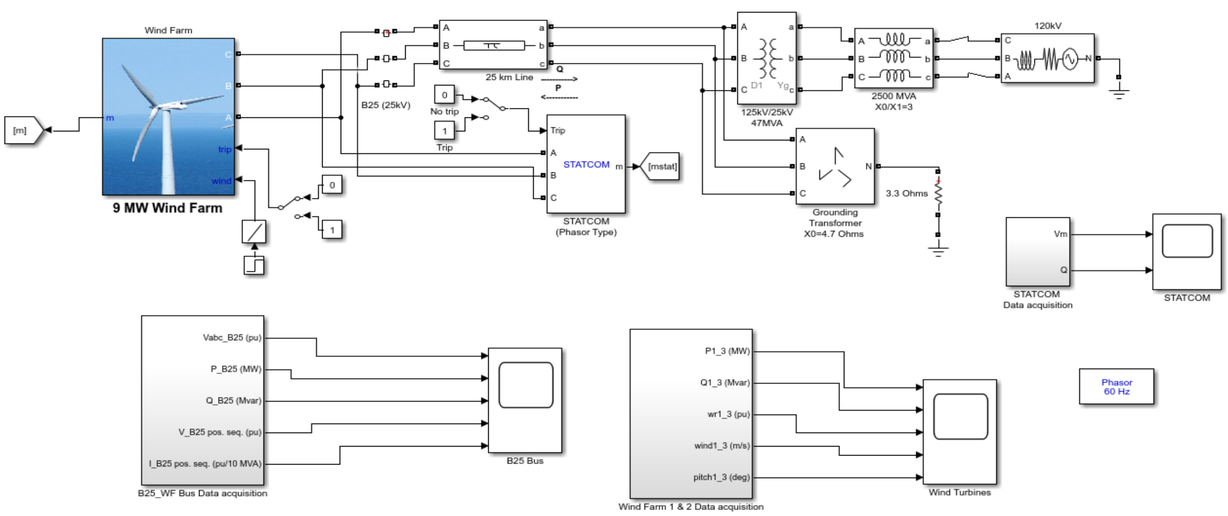


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Figure 4 Simulink Model

Wind turbines with a total capacity of 9 MW are shown in the Figures. 5 and 6. An induction generator in a squirrel cage is used in wind turbines Figure 7. Capacitor banks deliver reduced reactive power on the low voltage bus of each wind turbine (400 kVAR for each pair of 1.5- MW turbines). With a droop setting of 3 percent, the 3-Mar STATCOM produces the remaining reactive power needed to maintain the 25-kV voltage at bus B25 close to 1 pm. Windings of the stator winding are directly connected to the 60Hz grid and have variable pitch. This direct connection drives the rotor. Wind speeds above 9m/s are confined to the generator output power's nominal value, which is achieved by altering the pitch angle.

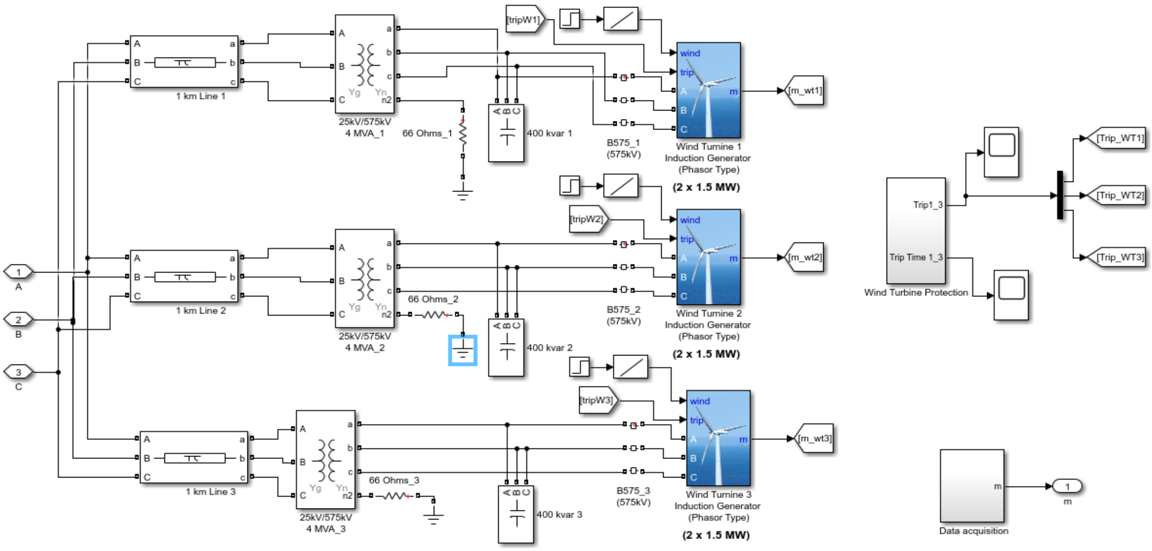

Figure 5 Detailed Model of Wind Farm without fault.

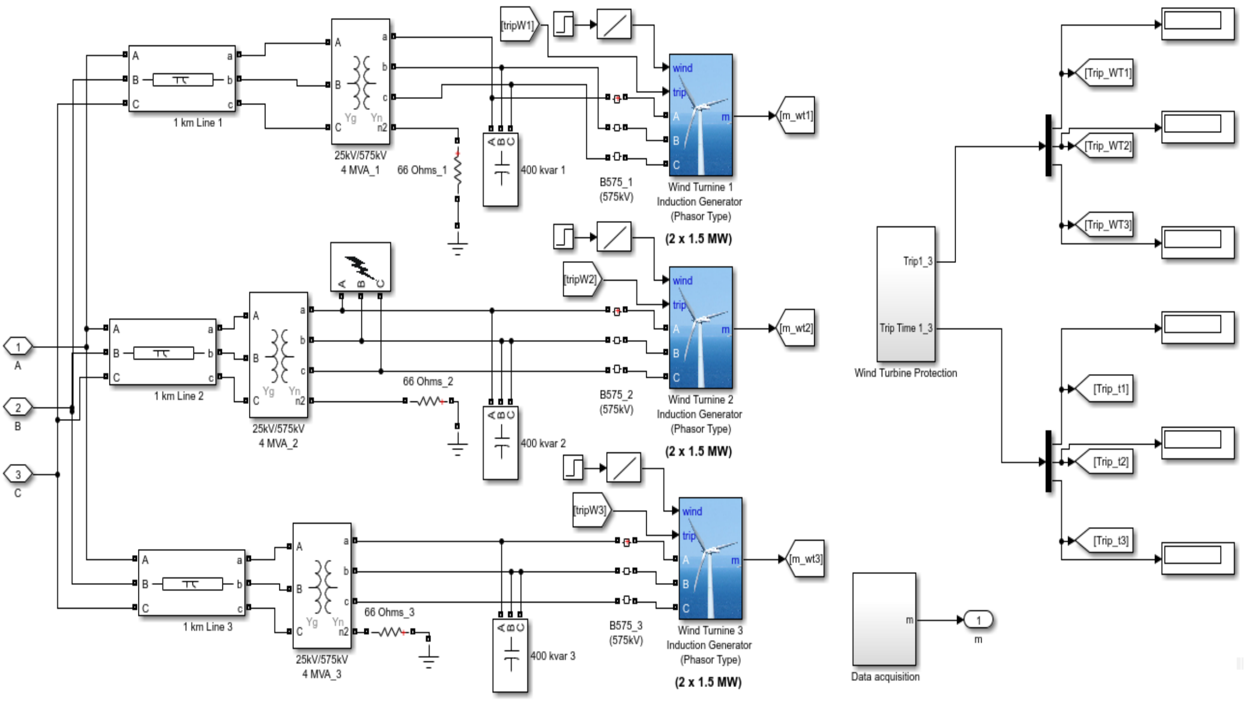

Figure 6 Detailed Model of Wind Farm when the fault is at Generator 2.

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The induction generator's speed must be slightly above the synchronous speed to create electricity. Weightless, the speed is between 1 and 1.005 psi, depending on the model. a safety system keeps tabs on the wind turbine's voltage, current, and rotation speed.

CASE-I NORMAL CONDITION WITHOUT STATCOM

Due to the lack of reactive power supply, the voltage at Bus "B25" drops to 0.91 pm when the model is operated normally without STATCOM linked to the system. Low voltage will cause the induction generator on Wind Turbine 1 to overheat. To illustrate the output of wind turbine one at t=13.36 seconds in Figure 7. The two remaining turbines will generate the final 6-MW. An over-current trip of the Wind Turbine Protection System happens.

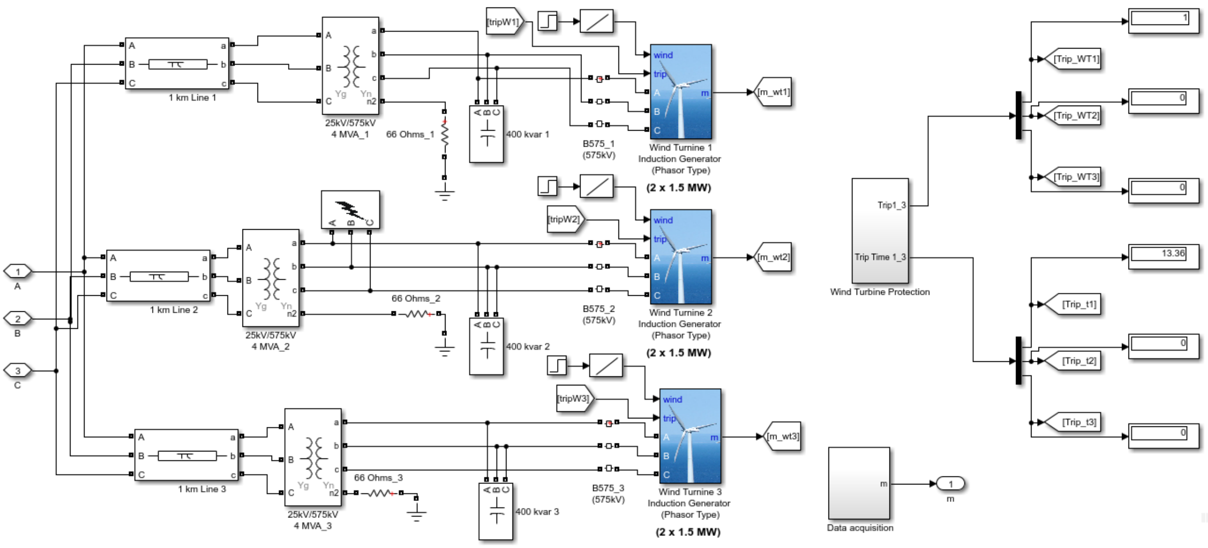

Figure 7 Wind farm

CASE-II NORMAL CONDITION WITH STATCOM

Wind Turbine 1's trip in Case-I due to a lack of reactive power supply will be compensated for by a Static Synchronous Compensator (STATCOM) (STATCOM). When the capacitor bank cannot provide the reactive power needed to keep the system voltage stable, the 3-Mar STATCOM steps in to provide reactive power, ensuring that all three turbines continue to supply power, as shown in Figure 8.

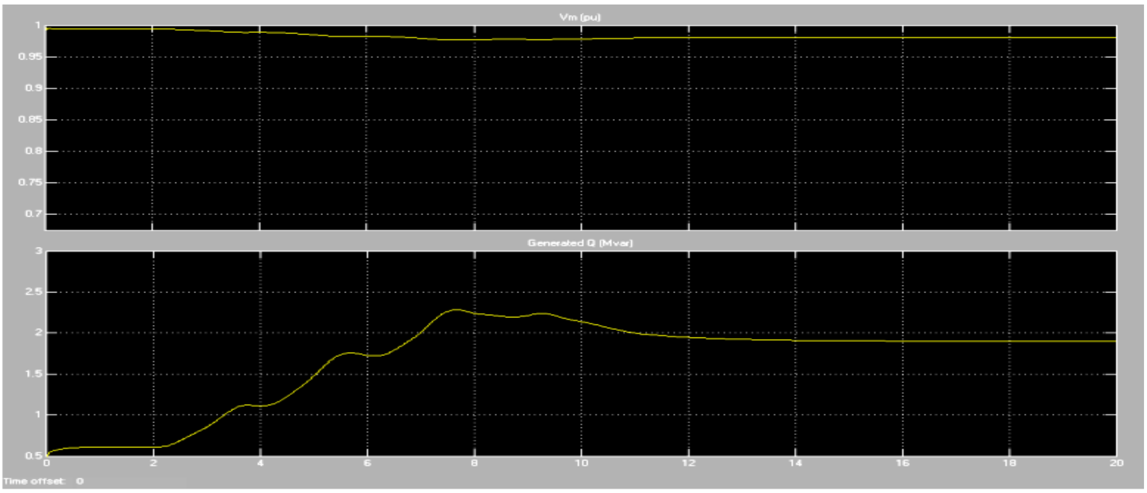

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Figure 8 STATCOM Scope

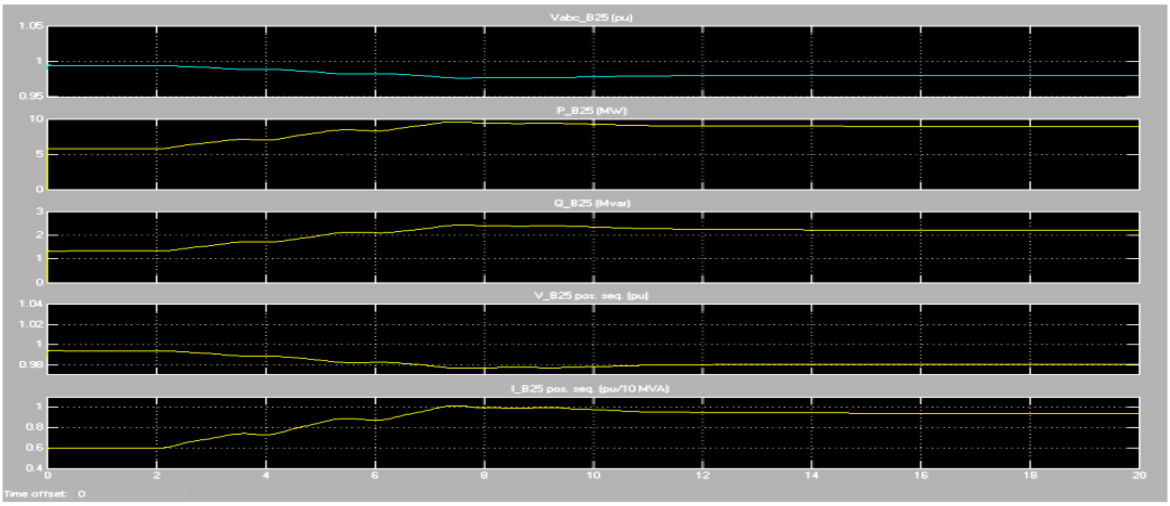

Figure 9 "B25 Bus Output"

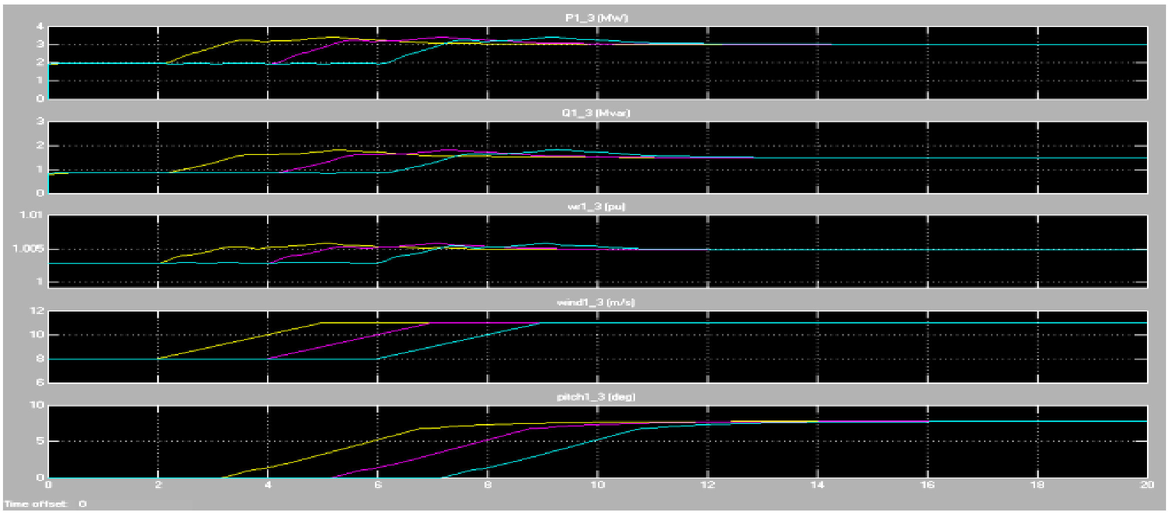

Figure 10 Wind Turbines Output

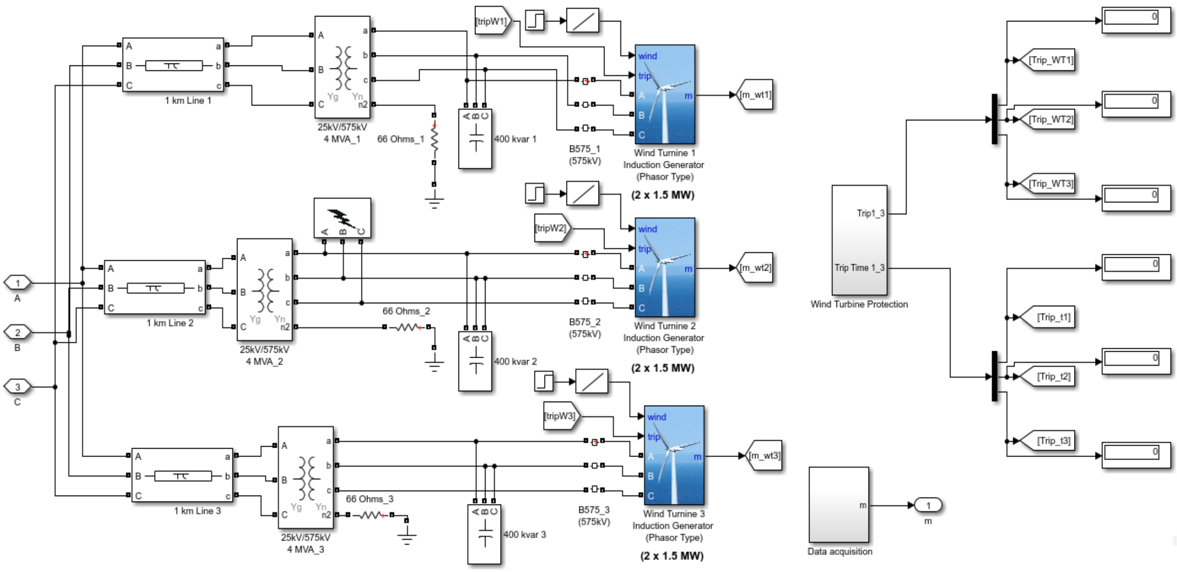

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Figure 11 Wind Farm

CASE-III PHASE TO PHASE FAULT WITHOUT STATCOM AT GENERATOR 2

If Generator 2 fails and STATCOM is not connected to the system, as shown in Figure 15, the problem begins after 15 seconds. Voltage drops to 0.91 volts at Bus "B25" in the beginning due to the lack of reactive power support, as shown in Fig. 14. Wind turbine 1's low voltage will cause induction generator 1 to overheat. Wind turbine number one is turned off for a total of 13.36 seconds in Figure 15. To demonstrate the over-current protection scheme has been activated, Wind Turbine Protection System just over five seconds later, Turbine 2 is shut down due to a fifteen-second-long malfunction. The Turbine Protection System is tripped by voltage protection. Voltage fluctuations have made it unstable before the two excursions have even begun.

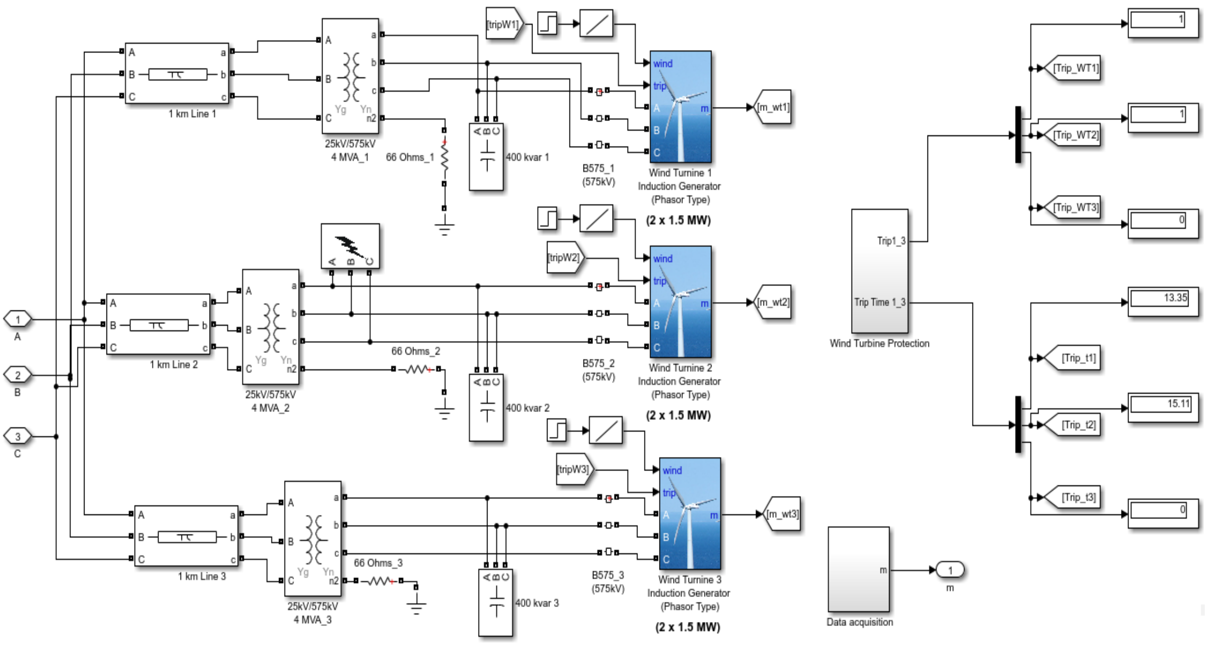

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Figure 12 Wind Farm

CASE-IV PHASE TO PHASE FAULT AT GENERATOR 2 WITH STATCOM

The problem arises at t=15 seconds after the STATCOM is connected (Figure 13). The 3-Mvar STATCOM helps keep the system voltage at or near one p.u because it provides the necessary reactive power. As a result, the system's output at Voltage 1 p.u remains stable at 9 MW. Phase-to-phase fault occurred at wind turbine two terminals 15 seconds after time zero, causing the turbine to trip at t:15.11 seconds" (Figure 14). AC trip in the "Wind Turbine Protections" section. If two turbine failure occurs, the remaining 3 MW will be generated by turbines 1 and 3.

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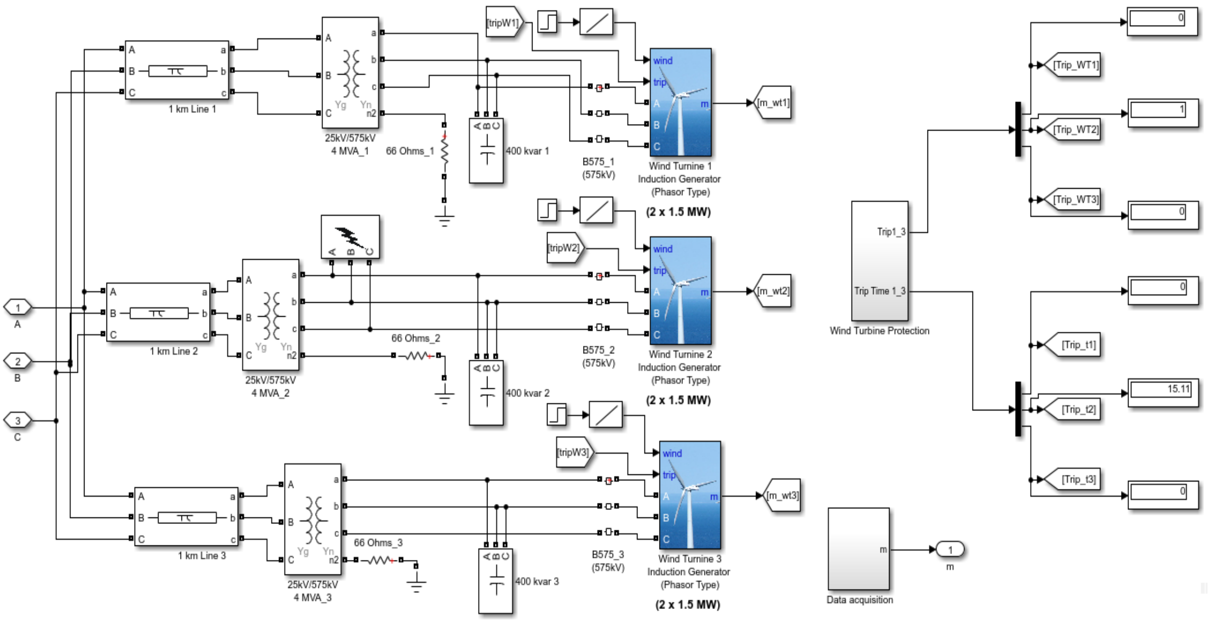

Figure 13 Wind Farm

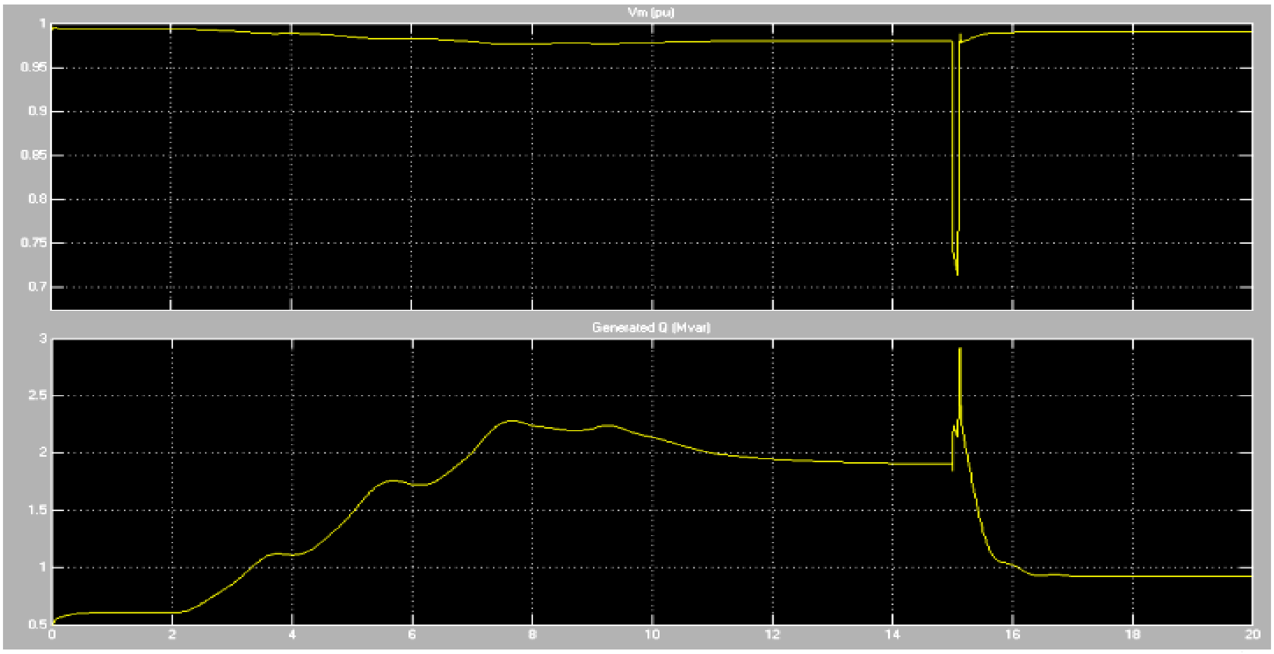

Figure 14 STATCOM Scope

CONCLUSION

This paper presents power quality improvement based on the control by FACTS device such as STATCOM for wind power plants helps in the power quality improvement. Poor electrical

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quality can have serious repercussions. MATLAB/SIMULINK has been used to create STATCOM's control system to preserve the simulated power quality. Using harmonic currents can be avoided entirely. The performance of the Wind power plant is tested by applying 3 phase fault conditions. Wind power plants require reactive power, and this device helps to keep the source voltage and current in phase. Phase-to-phase fault and power operating conditions are utilized to test the STATCOM controller's impact on electrical system operation. Results obtained through STATCOM control support that it can improve stability, attenuate power swings, regulate voltage, and manage reactive power. Because of this, more efficient use of the transmission lines is feasible.

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