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Performance Analysis of SCIG Coupled With Wind Turbine with and Without Fault

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Abstract- *This paper represents the modern investigation on incredible wind energy in real world. In this paper we have introduced a wind power in a power generation and transmission system alongside the conventional 3-phase sources and have simulated its working and performance. The wind power is made to work in tandem with the regular supply at first. In case of faults occurring in the system wind power is used to act as backup for the original supply. Also in case of extra power demand in peak time periods, it has been used to complement the power sources thereby maintaining the power quality and frequency in the system. The aim of this paper is to provide the basic concepts to understand a wind energy generation system and the way it must be operated to be connected to the utility grid. This also includes simulation of 9MW wind farm power using Squirrel Cage Induction Generator (SCIG) by variable pitch wind turbine. . All these scenarios have been simulated with the help of the simulation program using MATLAB and its inbuilt components provided in Simulink library.*

Keywords- *Squirrel cage Induction Generator (SCIG), Static synchronous compensator (STATCOM)*

I. INTRODUCTION

The wind power is a pollution free source of energy. Over the last twenty-five years, renewable energy sources have been attracting great attention due to the cost increase, limited reserves and adverse environmental impact of fossil fuels. In the meantime, technological advancements, cost reduction, and governmental incentives have made some renewable energy sources. This paper provides an overview of wind energy conversion system (WECS) and their related technologies. The aim of the paper is to provide a background on several aspects relating to this exciting technology and market trends such as installed capacity, growth rate, and costs. The details of turbine component system configuration, and control scheme are analyzed in depth. Installed wind power capacity has been progressively growing over the last two decades. Figure 1 shows the global annual installed wind capacity (1996-2013).The wind industry has achieved an average growth rate of over 25% since 2000 and is expected to continue this trend in the coming years. This impressive growth has been spurred by the continuous cost increase of classic energy sources, cost reduction of wind turbines, governmental incentive programs, and public demand for cleaner energy resources.

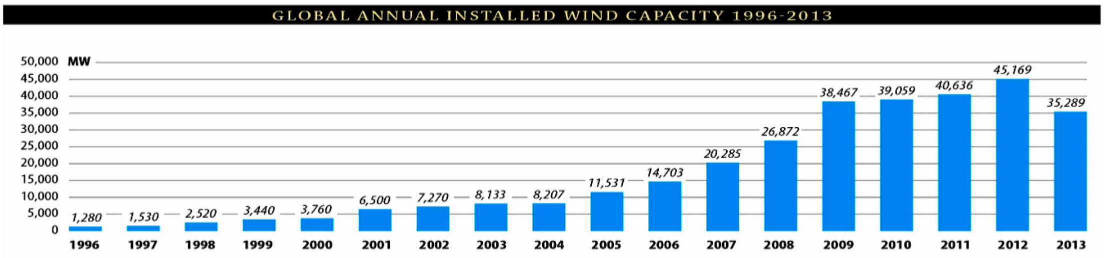


Figure 1. Global annual installed wind capacity (1996-2013)

II. THE POWER IN THE WIND

The wind systems that exist over the earth's surface are a result of variations in air pressure. However, significant areas of the world have meant annual wind speeds of above 4-5 m/s (meters per second) which makes small-scale wind powered electricity generation an attractive option.

$$\text{Power} = \frac{\text{density of air x swept area x velocity cubed}}{2}$$

$P = ½.\rho.A.V^3$

Where, P is power in watts (W)

ρ is the air density in kilograms per cubic meter (kg)

A is the swept rotor area in square meter (m2)

V is the wind speed in meter per second (m/s)

The fact that the power is proportional to the cube of the wind speed is very significant. This can be demonstrated by pointing out that if the wind speed doubles then the power in the wind increases by a factor of eight. It is therefore worthwhile finding a site which has a relatively high mean wind speed.

III. FACTS DEVICES

FACTS device can be effectively used for power flow control, load sharing among parallel corridors, voltage regulation enhancement of transient stability and mitigation of system oscillation. Facts employ high speed thyristors for switching in or out transmission line component such as capacitors reactors or phase shifting transformer for some desirable performance of systems. Facts devices can be classified on the basis of connection.

(a). Shunt compensator (b). Series compensator

STATCOM is a static synchronous generator operated as shunt connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system transmission voltage by reactive shunt compensation. It can be based on voltage source or current source converter. STATCOM can be designed to be an active filter to absorb system harmonics voltage. A combination of STATCOM and an energy source to supply or absorb power is called static synchronous generator (SSG). Energy source may be a battery, flywheel, superconducting magnet, large dc storage capacitor, another rectifier/inverter etc.

IV. MODELING AND SYSTEM ANALYSIS OF A COMPENSATED SCIG SUBJECT TO FAULT

Simulation of 9MW wind farm power using Squirrel Cage Induction Generator (SCIG) by variable pitch wind turbine.

This model consists of a 9MW wind form which is consisting of six 1.5-MW wind turbines is connected to a 25-kV distribution system exports power to a 120-kV grid through a 25-km 25-kV feeder. The 9-MW wind farm is simulated by three pairs of 1.5 MW wind-turbines. Wind turbines use squirrel-cage induction generators (IG). The stator winding is connected directly to the 60 Hz grid and the rotor is driven by a variable-pitch wind turbine. The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load. Each wind turbine has a protection system monitoring voltage, current and machine speed.

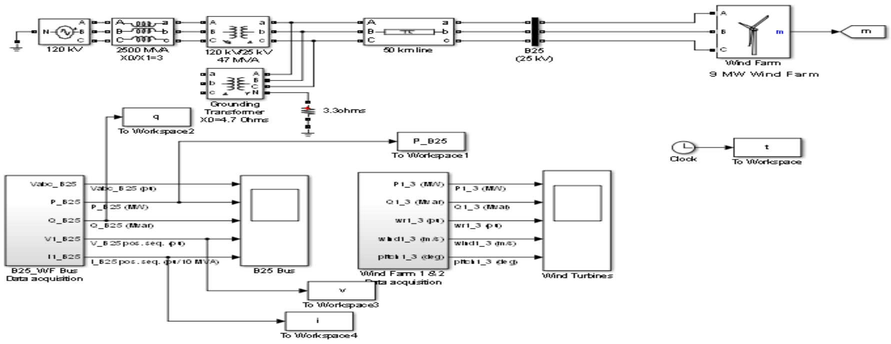
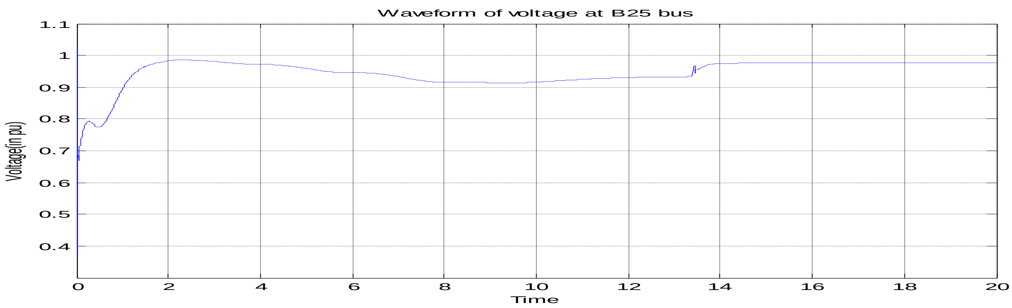
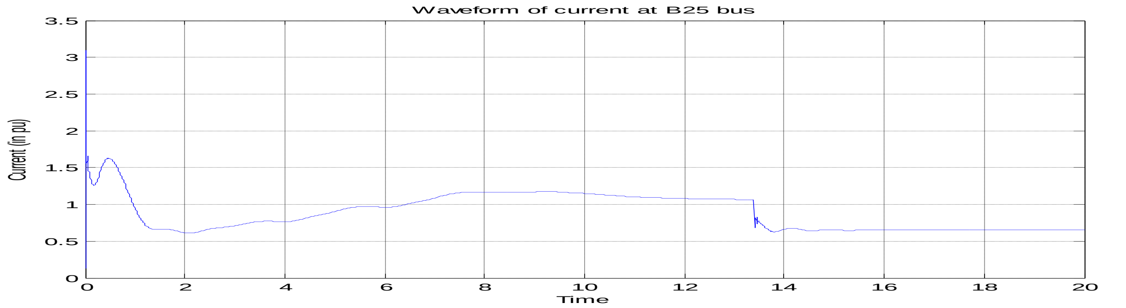


Figure 2. Model of wind farm using SCIG

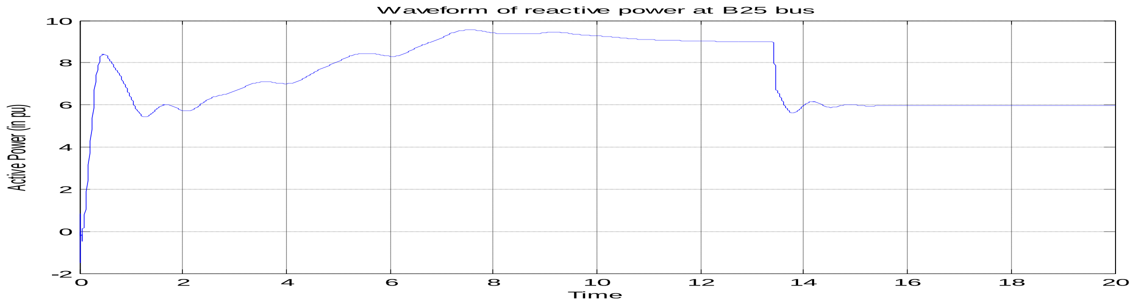
Waveform of output voltage, current, active power and reactive power at B25 bus here we have observed, the output waveform of output voltage and current at B25 bus which is in per unit (pu)



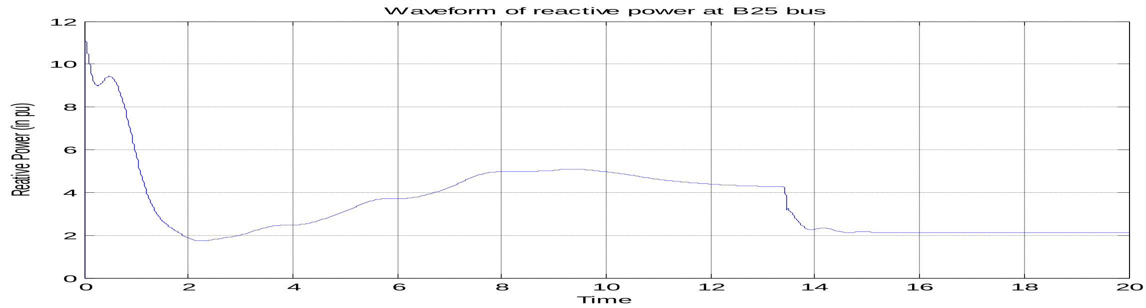
The voltage waveform, as shown above, at the time of starting decreases then increases and finally saturates at t=14s, becomes .998pu.



The current waveform, as shown above, at the time of starting increases then decreases and finally saturates at t=14s, becomes .75pu.



The active power waveform, as shown above, at the time of starting increases suddenly then decreases and finally saturates at t=14s, becomes 6MW



The reactive power waveform, as shown above, at the time of starting decreases rapidly then increases and finally saturates at t=14s, becomes 2.05MVAr

Simulation model of 9MW wind farm using SCIG and phase to phase fault at wind turbine-two

In subsystem model, at t=15 sec, a phase to phase fault is applied at wind turbine 2 terminals, causing the turbine to trip at t=15.11 s. If we look inside the "Wind Turbine Protections" block we will see that the trip has been initiated by the AC Under voltage protection. After turbine 2 has tripped, turbines 1 and 3 continue to generate 3 MW each.

Waveform of voltage and current at B25 bus, when phase to phase fault is occurred at output terminal of wind turbine-2. Hence at t=15s when fault is occurred, voltage suddenly decreases and when fault is cleared voltage becomes approximately 1pu.

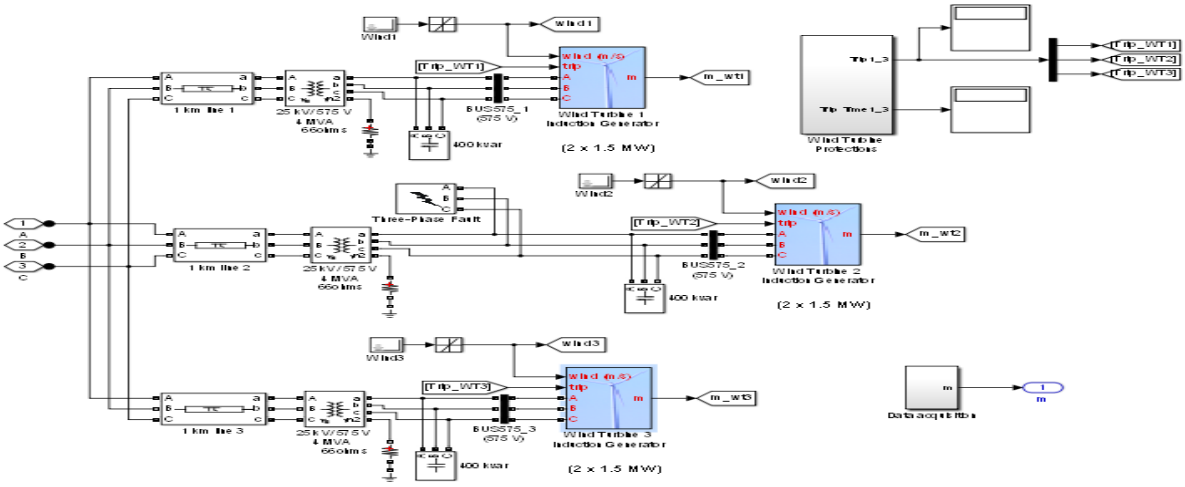
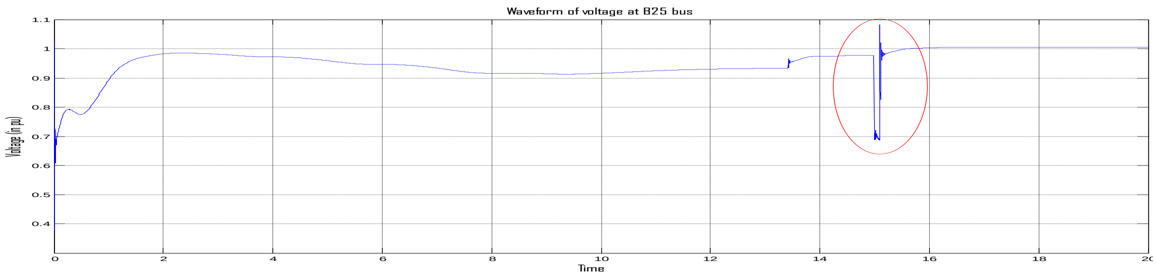
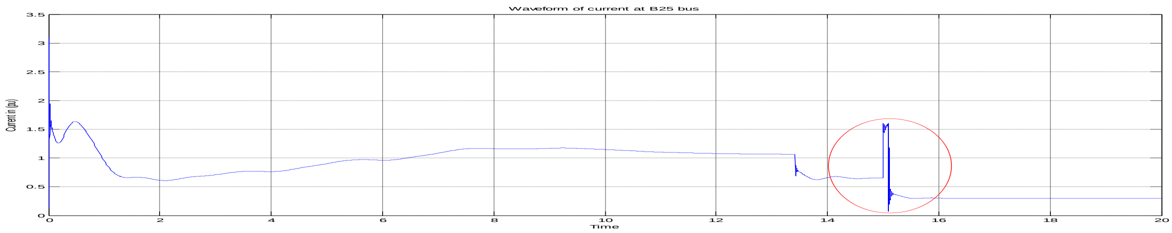


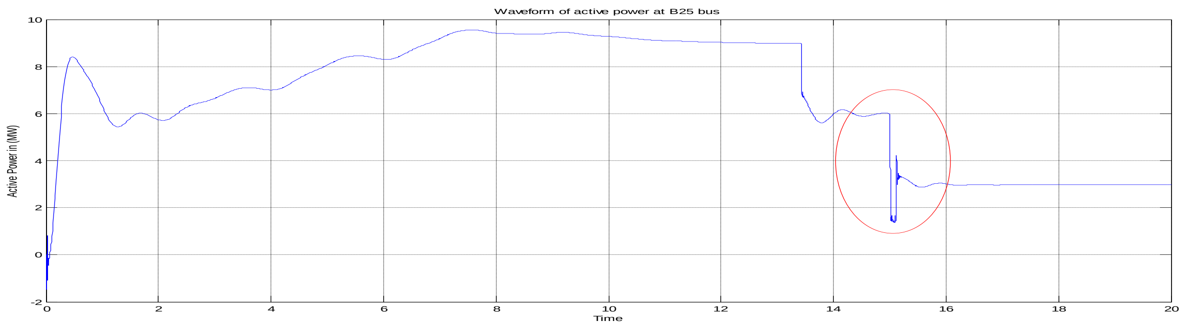
Figure 3. Phase to phase fault at wind turbine-2



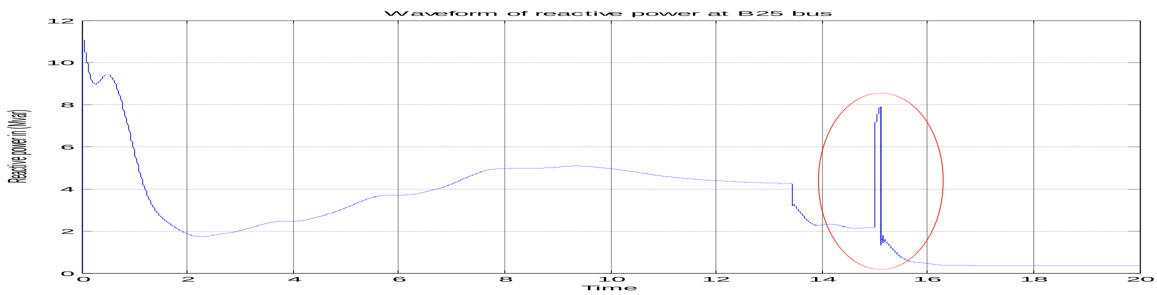
The voltage waveform, as shown above, at the time of starting decreases then increases and at the time of phase to phase fault, voltage suddenly decreases(shown inside ellipse) and finally saturates to 1pu.



The current waveform, as shown above, at the time of starting increases then decreases and at the time of phase to phase fault, current suddenly increases(shown inside ellipse) and finally saturates to .25pu.



The active power waveform, as shown above, at the time of starting decreases then increases and at the time of phase to phase fault, voltage suddenly decreases(shown inside ellipse) and finally saturates to 3MW.



The reactive power waveform, as shown above, at the time of starting increases then decreases and at the time of phase to phase fault, voltage suddenly increases (shown inside ellipse) and finally saturates to .75MVAr.

Simulation of wind power model using STATCOM

When STATCOM is connected to the output terminal of the wind farm of 9MW wind turbine. We observe on "B25 Bus" scope that because of the lack of reactive power support, the voltage at bus "B25" now drops to 0.91pu. This low voltage condition results in an overload of the IG of "Wind Turbine 1". "Wind Turbine 1" is tripped at t=13.43 s. If we look inside the "Wind Turbine Protections" block we will see that the trip has been initiated by the AC over current protection.

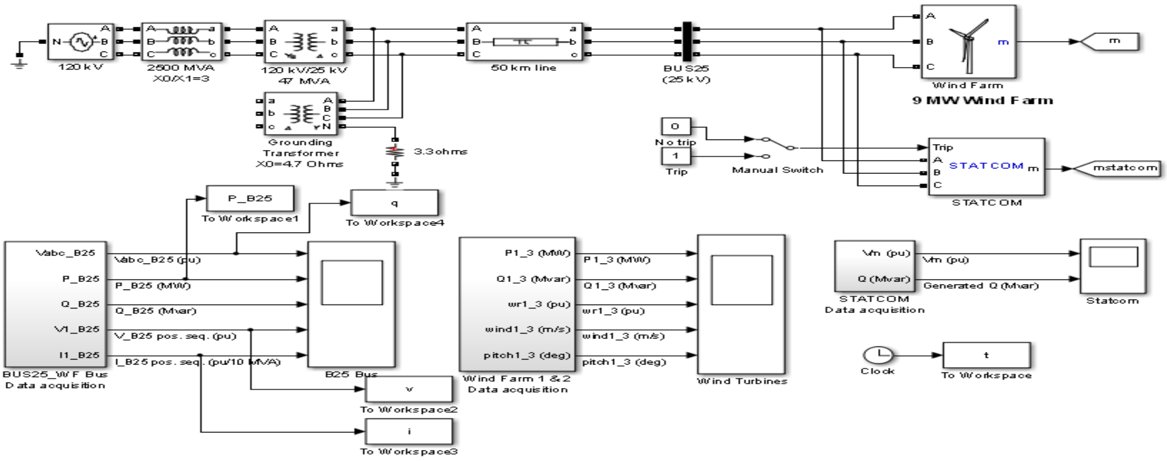
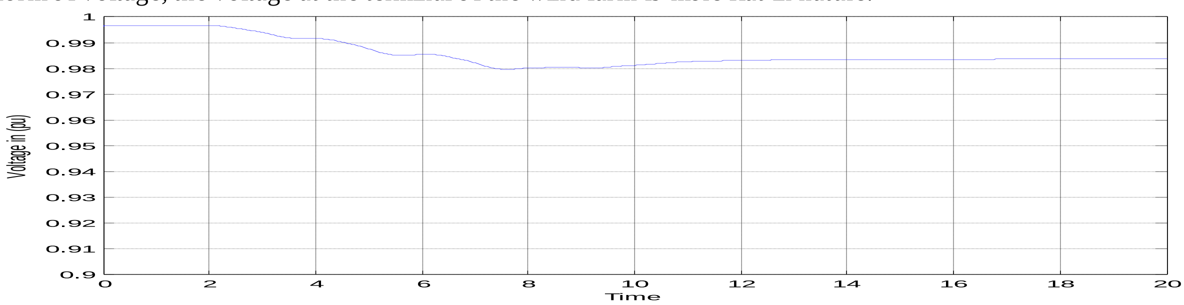


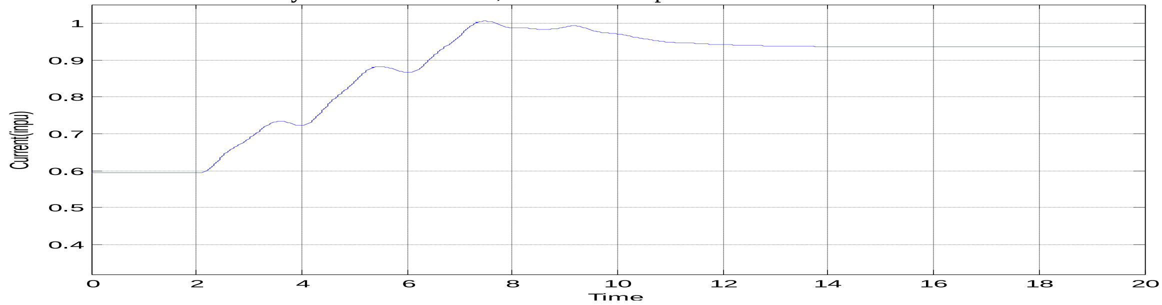
Figure 4. Wind power model using STATCOM

Output Waveform of Voltage, Current, Active Power and Reactive Power

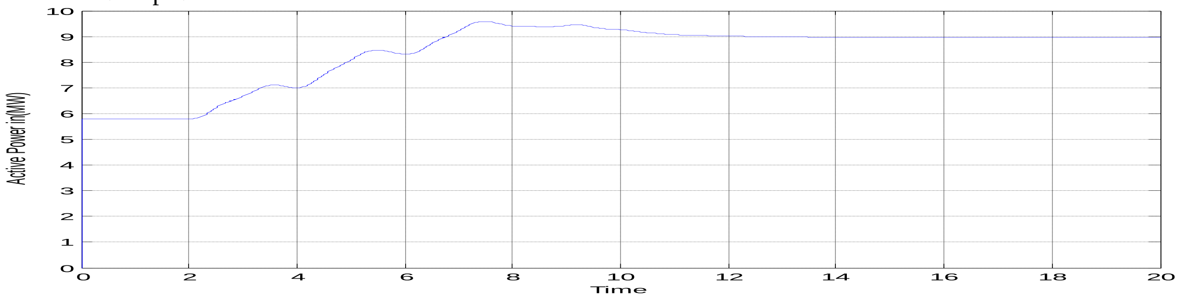
STATCOM is a device which is used to improve the voltage profile of the system. We have observed that the waveform of voltage, the voltage at the terminal of the wind farm is more flat in nature.



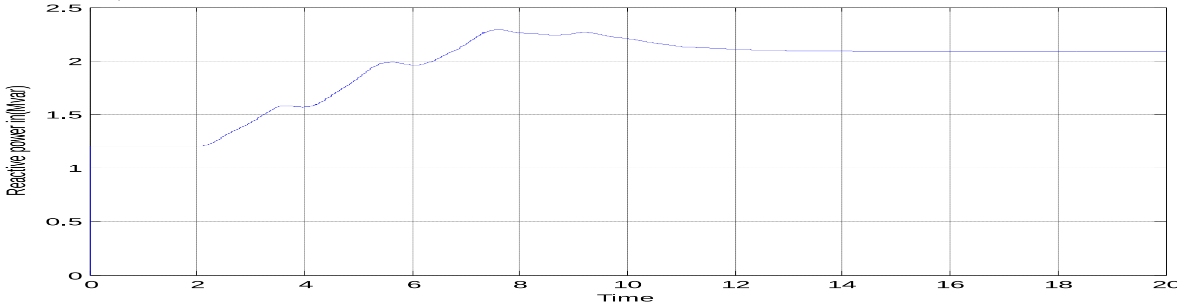
When STATCOM is connected, the voltage waveform improves, as shown above, at the time of starting decreases then increases and finally saturates at t=14s, becomes .988pu.



The current waveform, as shown above, at the time of starting decreases then increases and finally saturates at t=14s, becomes .998pu.



The active power waveform, as shown above, at the time of starting decreases then increases and finally saturates at t=14s, becomes 9MW.



The reactive power waveform, as shown above, at the time of starting decreases then increases and finally saturates at t=14s, becomes 2.1MVAr.

Wind power model using turbine speed of all turbine 8mps

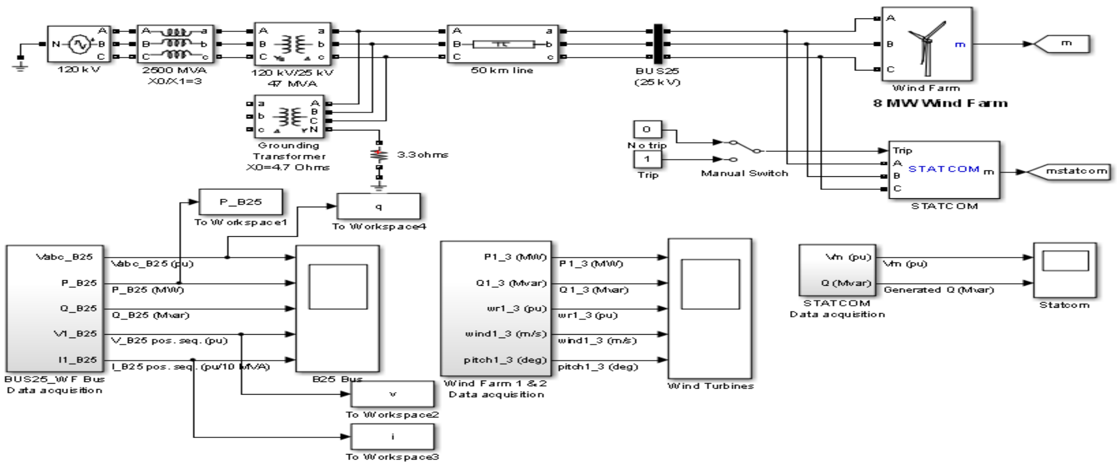
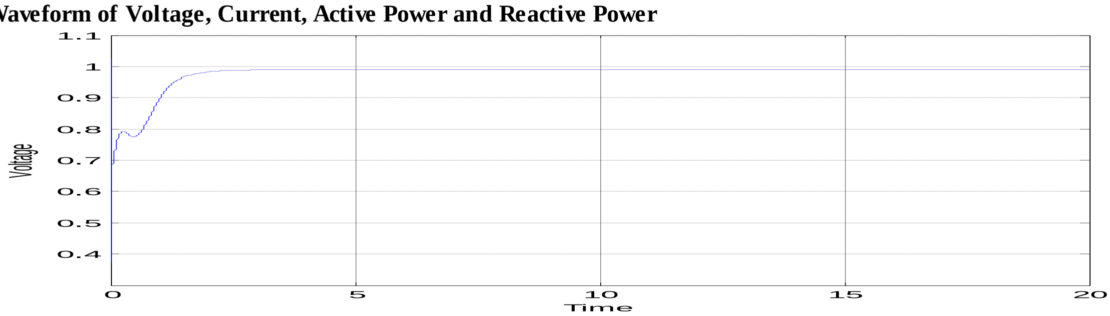
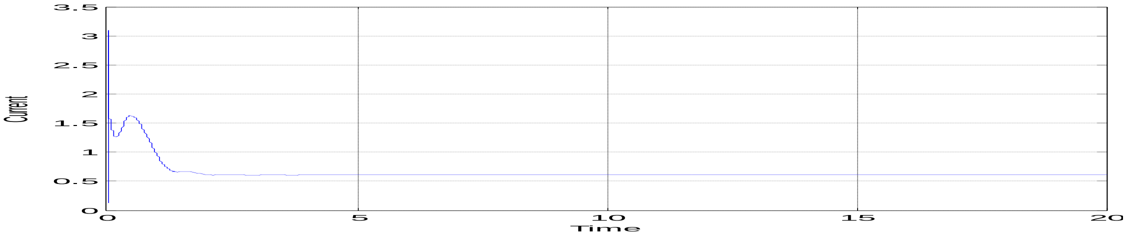


Figure 5. Wind power model using turbine speed of all turbine 8mps

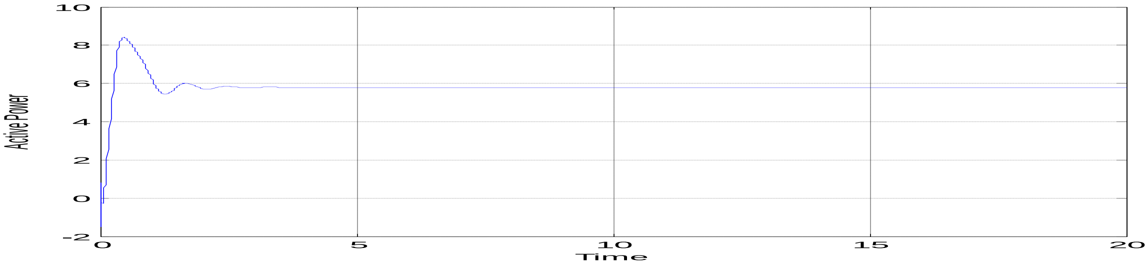
Output Waveform of Voltage, Current, Active Power and Reactive Power



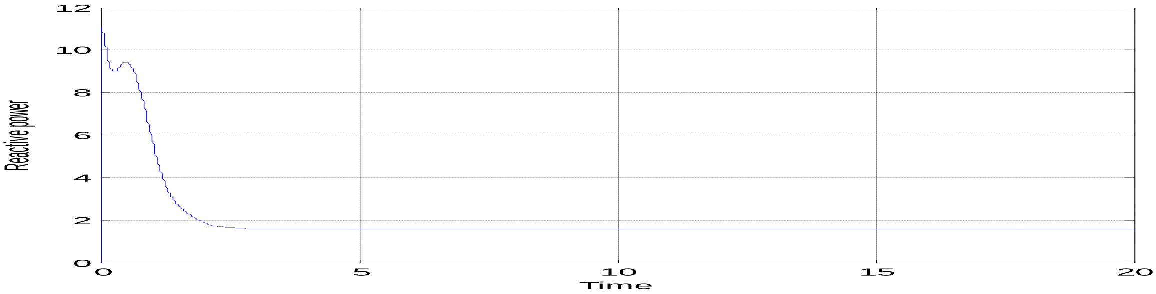
When all the wind turbine are started together, the waveform of output voltage is obtained which is shown above .the waveform of the voltage becomes smoother



When all the wind turbine are started together, the waveform of output current is obtained which is shown above .current waveform also becomes smoother



When all the wind turbine are started together, the waveform of output active is obtained which is shown above .The active power waveform also becomes smoother.



When all the wind turbine are started together, the waveform of output reactive power is obtained which is shown above. The waveform of reactive power also becomes smoother.

V. RESULTS

Result of Output Waveform With Fault and Without Fault Using STATCOM

1. Without fault (with the time of introduction of turbine being t=12 seconds)

(a). At t=0s, V=.989pu,
At t > = 12s, V=.979pu

(b).At t=0s, i=.15pu,
At t > = 12s, i=.3pu,

(c).At t=0s, P=1.5MW'
At t > =12s P=3MW'

(d). at t=0s, Q=.8Mvar,
At t > = 12s, Q=1.7Mvar

Thus we observe that the introduction of turbine at t=12 seconds brings an improvement in the current, real power and reactive power

2. with Fault

(a). At t=0s, V=.98pu,
At t = 15s, V=.7pu

(b).At t=0s, i=.1pu,
At t = 15s, i=1.6pu,

(c).At t=0s, P=1.4MW'
At t =15s P=-.5MW'

(d). at t=0s, Q=.8Mvar,
At t = 15s, Q=7.5Mvar

Thus we observe that the introduction of fault at wind turbine terminal two at t=15 seconds, we see that voltage reduces suddenly and reactive power increases rapidly. Also in general three phase fault voltage reduces rapidly

Result of Output Waveform With Fault and Without Fault, Without STATCOM

1. without fault

(a). At t=0s, V=.68pu,
At t > = 15s, V=.98pu
(b).At t=0s, i=1.35pu,
At t > = 15s, i=.7pu,
(c).At t=0s, P=8.2MW'
At t > =15s P=6MW'
(d). At t=0s, Q=1.1Mvar,
At t > = 14s, Q=2.1Mvar
WITHOUT STATCOM we have observed that voltage and reactive power reduces (with STATCOM).we have used STATCOM which compensate the reactive power generated by 9 MW wind turbine
2. with Fault
(A). at t=0s, V=.7pu,
At t = 15s, V=.90pu
(B). at t=0s, i=.1pu,
At t = 15s, i=1.6pu,
(c) .At t=0s, P=8.2MW'
At t =15s P=1.5MW'
(d). At t=0s, Q=11Mvar,
At t = 15s, Q=7.9Mvar
Thus we observe that the introduction of fault at wind turbine terminal two at t=15 seconds, we have observed that voltage reduces suddenly and reactive power increases rapidly. Also in general three phase fault voltage reduces rapidly, but the variation in voltage dip is more than above cases, in which STATCOM is used

VI. CONCLUSION

We can conclusively say that wind power has the capability to supply conventional systems both as a backup supply and as a main supply. In case of faults occurring in the system wind power is used to act as backup for the original supply. Also in case of extra power demand in peak time periods, it has been used to complement the power sources thereby maintaining the power quality and frequency in the system. When STATCOM is connected in system, the voltage and active power improves and reactive power decreases.

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