Voltage control of grid connected wind generation system using DSTATCOM

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Abstract—Recently the usage of distribution generation has significantly increased in the electric power distribution system.Wind generation system has potential application for the grid support.when integrated to the power system ,large wind farms pose stability and control issues A through study is needed to identify the potential problems and develop measures to mitigate them .Although integration of high levels of wind power into existing transmission system does not require a major redesign it necessities additional control and compensating equipment . The voltage of the wind generators is variable due to the intermittent nature of the wind energy. Fluctuating voltage is of major concern in the grid connected wind generation systems, this paper investigates use of a static synchronous compensator (DSTATCOM) along with wind farms for purpose of stabilizing the grid voltage The results are validated using matlab simulink simulation studies.

Index Terms—STATCOM,busbar,wind turbine ,wind generation,grid, fuzzy logic controller

1 INTRODUCTION

Due to increasing electricity demand, the power stations are getting short of power required by the consumers. Researchers have diverted their study to find out alternate source of energy, i.e., distributed generation. There are various types of distributed sources, out of them wind source is the better option as the power in megawatts range can be generated. This is a feasible power level to be interfaced to the power grid. For wind turbines connected to the weak grid system, the significant power fluctuation in the grid would lead to the reduced quality of power supply to the load.These weak grid systems need appropriate control systems to smooth out the fluctuations without sacrificing the peak power tracking capability. The power converter based controller is an option to track the peak power output of the wind energy system and to maintain the quality of voltage supply to the users. Small scale stand alone wind energy systems are an important alternative source of electrical energy that is finding applications in the locations where conventional generation is not practical. Unfortunately, most of these systems do not capture power for all wind speed, specially at low speeds- -which are low in power. Small standalone wind systems can generate power which can be used locally. However, if the power demand at the load end is less, the wind generators can be interfaced with the grid to supply extra power generated. Also, if the power demand is high it can be received from the grid. The overall system has better efficie cy, simplicity and ruggedness .

The major problem which is faced with the wind generation systems are variation in supply frequency and fluctuating power. These are important concern for the grid connected wind power generation systems. To address these problems, a control strategy has been proposed in this paper.

Wind turbines convert the kinetic energy present in the wind into mechanical energy by means of producing torque. Since the energy contained by the wind is in the form of kinetic energy, its magnitude depends on the air density and the wind velocity. The wind power developed by the turbine is given by the equation (1)

$$P_{turb} = \frac{1}{2} \rho A C_p V_w{}^3 \qquad (1)$$

Where *Cp* is the Power Co-efficient, ρ is the air density in kg/m^3, *A* is the area of the turbine blades in m^2 and *V* is the wind velocity in m/sec. The power coefficient *Cp* gives the fraction of the kinetic energy that is converted into mechanical energy by the wind turbine. It is a function of the tip speed ratio *(TSR)* and depends on the blade pitch angle for pitch-controlled turbines. The tip speed ratio may be defined as the ratio of turbine blade linear speed and the wind speed given by equation (2).

$$TSR = \frac{R\omega}{V} \qquad (2)$$

The use of static power converters in electricity networks has the potential of increasing the capacity of transmission of electric lines and improving the supply quality of the electric energy. The devices used to achieve this, are the FACTS devices. According to the IEEE the definition of these FACTS devices is the following: “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability. The FACTS controllers offer great opportunities to regulate the transmission of alternating current (AC), increasing or diminishing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between distant agents.

Flexible AC Transmission Systems (FACTS) components such as the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC) are being used increasingly in power systems because of their ability to provide flexible power flow control. The main motivation for choosing STATCOM in wind farms is its ability to provide bus bar system voltage support either by supplying and/or absorbing reactive power into the system.

2 LITERATURE SURVEY

Ref [1] In this paper use of statcom for improving dynamic performance of wind farm which is connected to power grid is carried out

Ref [2] In this paper mathematical models for a three phase three-level Static Synchronous Compensator (STATCOM) working with both fundamental frequency modulation and selective harmonic elimination modulation. The mathematical models were simplified to obtain the STATCOM ac side current, the dc capacitor voltage and the ripple for both switching strategies

Ref [3] This paper represents Flexible AC Transmission System (FACTS) as a new technology based on power electronics that offers an opportunity to enhance controllability, stability, and power transfer capability of AC transmission systems

Ref [4] This paper investigates the dynamic operation of novel control scheme for Static Synchronous Compensator (STATCOM) based on a new full model comprising a 48-pulse Gate Turn-Off hyristor voltage source converter for combined reactive power compensation and voltage stabilization of the electric grid network

Ref [5] In this paper the use of the static synchronous compensator (STATCOM) for wind farm integration. Wind farm models based on fixed speed induction generators (FSIG) using AC connection and equipped with STATCOM are developed. It was found that the STATCOM considerably improve the system stability during and after disturbances, especially when the network is weak. It showed that the STATCOM gave a much better dynamic performance, and provided better reactive power support to the network, as its maximum reactive current output was virtually independent of the PCC voltage.

3. WIND GENERATION SYSTEM INTERFACE TO GRID

The wind turbines (WTs) considered in this system are Squirrel Cage Induction Generators (SCIG) that is driven by variable pitch wind turbine. A STATCOM was employed to regulate the voltage at the bus.

Fig 1. shows the test system i.e wind farm connected to grid (large bus of the local synchronous generator) through distribution line , interconnection of wind turbines to distribution line via transformer, and further interconnecting distribution line to grid via transformer. A STATCOM is connected as compensating device. Capacitor is connected at each bus for small compensation of reactive power.

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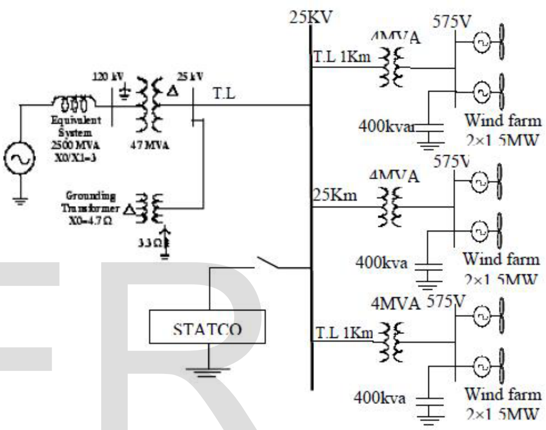

Fig 1.Test system

The model consistsof 9MW wind farms consisting of six 1.5 MW wind turbine generators connected to a 25 kV distribution system exporting power to 120 kV grid through a 25 km 25kV feeder as shown in Fig. 1. Two wind generators each are bused together with common excitation capacitor, capacitors provide low compensation in the system and wind turbines are connected to point of common coupling (25 kV bus) by different length of feeders. A STATCOM, an active voltage support, is connected to the junction bus of the generator. The STATCOM is connected to the system via a transformer

The wind turbine and the induction generator (WTIG) called squirrel-cage induction generator driven by variable pitch wind turbine. The stator winding is connected directly to the grid and the rotor is driven by the wind turbine. The power captured by the wind turbine is converted into electrical power by the induction generator and is transmitted to the grid by the stator winding.

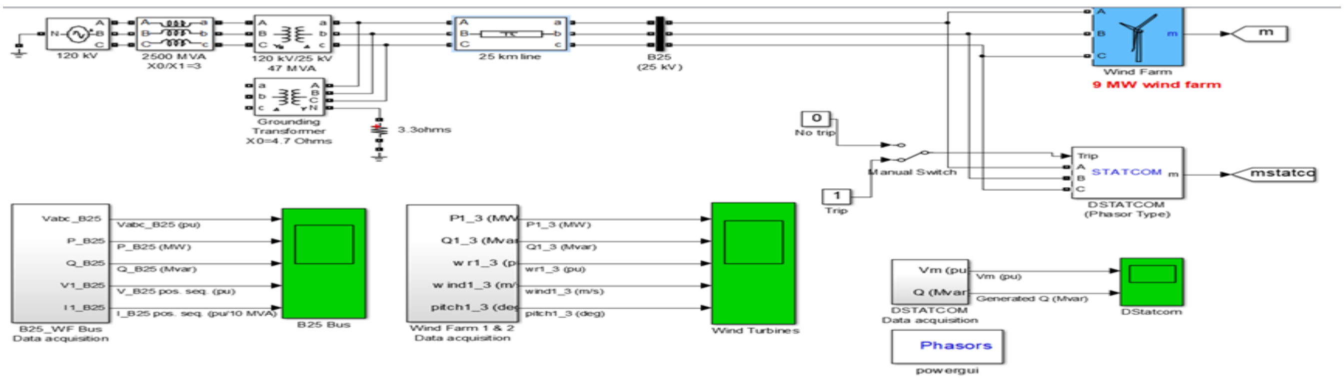

Fig2 test system

As the speed of wind is variable in nature,output voltage of wind generator is changes when speed of wind is changed ,9 MW wind model connected to 120 KV grid through 25 kV bus(pcc).the voltage at point of common coupling will be changed due to lack of reactive power in the system to maintain voltage support at 25 kv bus,STATCOM is connected at junctuin bus to provide voltage support to sytem bus by absorbing or generating reactive power to system . Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus (400 kvar for each pair of 1.5 MW turbine). The rest of reactive power required to maintain the 25-kV voltage at bus B25 close to 1 pu is provided by a 3-Mvar STATCOM

4. DETAILED MODEL OF WIND FARM

9 MW wind farm is simplified into 3 pairs of wind turbine, each pair has 2*1.5 MW wind turbines, 400Kvar capacitor bank are connected at each pair of bus to provide reactive power support absorbed by wind generators, three pairs of turbines connected to point of common coupling via transformer

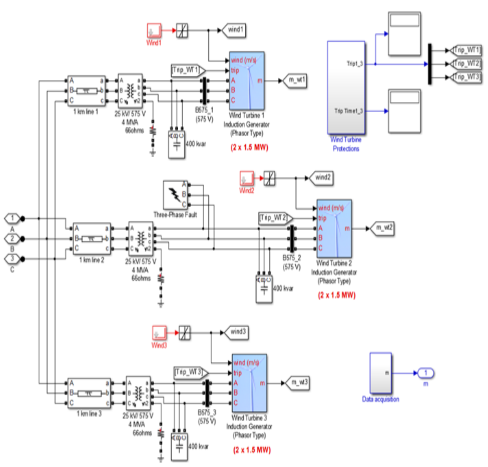

Fig 3 (wind farm)

5. FUZZY LOGIC CONTROLLER

In wind generation system integrated to grid a fuzzy logic controller is used to regulate voltage by STATCOM, selection of proper membership function is important in this controller,each membership function has mathematical equation, membership function is selected by trial and error method. Shape and range are main to define proper membership function for input and output variables.
The main aim for using fuzzy logic controller is to improve dynamic performance of grid connected wind generation system within short time duration and voltage deviation must be compensated in short time .
In fuzzy logic controller we have to create Rule base , rules will be in the form If then Else, in grid connected wind generation system creation of 5 rules has been propsed

1. If Vpu is very low then STATCOM signal should be high capacitive.

2. if Vpu is low then STATCOM signal should be low capacitive

3. if Vpu is normal then STATCOM signal should be normal

4. if Vpu is high then STATCOM signal should be low inductive

5.if Vpu is very high then STATCOM signal should be high inductive

The voltage from point of common coupling is fed to fuzzy controller as input, the controller reacts based on rules created and generates the reference signal (Vref) , the generated Vref signal is fed to STATCOM to provide voltage support to system bus by absorbing or generating reactive power in the system in short time duration.hence fuzzy logic controller is used as main to do injection within short duration.

6.DESCRIPTION OF DATAACQUISITION CIRCUIT

The following circuit is used for data acquisition in system

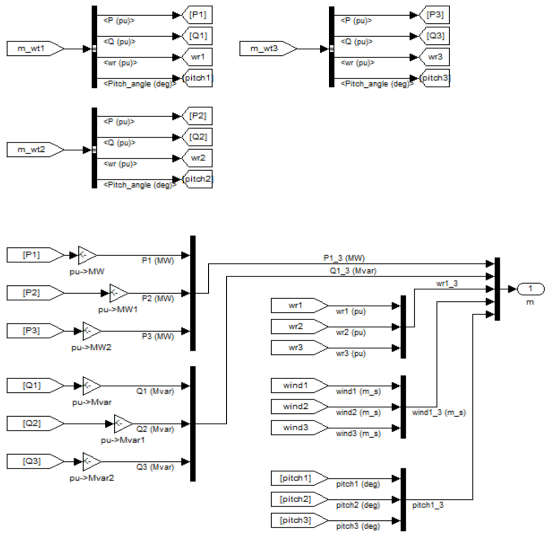

Fig 4(Data acquisition circuit)

6.1 Data acquisition circuit for 25 k.v bus

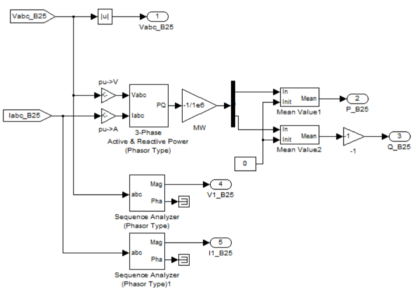

Fig 5(Data acquisition for 25 Kv bus)

It receives signal from the power_wing_ig/B25(25kv)/vabc. This is already defined in the toolbox

6.2 Data acquisition circuit of wind farm for wind turbine

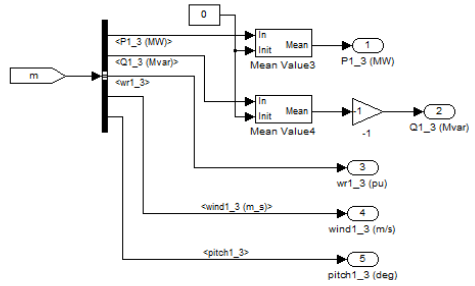

Fig 6 Data acquisition of wind farm

In above circuit, input is taken from output of the data main acquisition circuit of the wind farm

6.3 Data acquisition circuit for statcom model

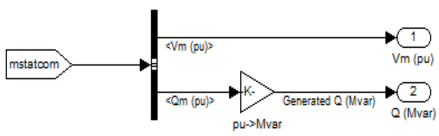

Fig 7 Data acquisition for STATCOM model

It receives signal from the power_wing_ig/goto1 i.e from the STATCOM which is already defined in the toolbox

7. RESULTS

7.1 Response of system without DSTATCOM

when the wind speed is varied from (8-11)m/s,without DSTATCOM the output active power for each pair of turbine is 3MW , observed reactive power for each pair of turbine Reaches 1.47Mvar, turbine speed for each pair of turbine Reaches to 1.005pu as shown in fig 8 8(a) because of lack of Reactive power support the voltage at bus 25KV now drops to 0.93 pu and variation of active and reactive power at 25 kv as shown in fig 8(b)

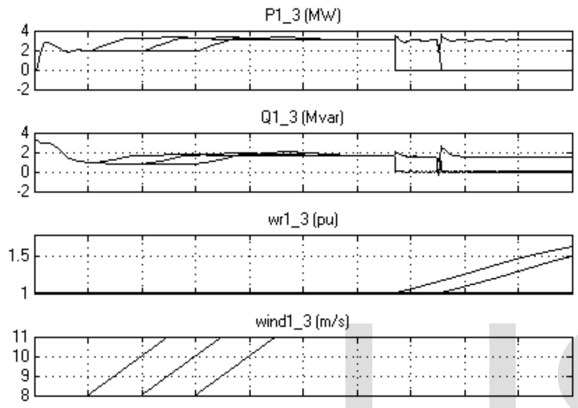

Fig. 8(a)

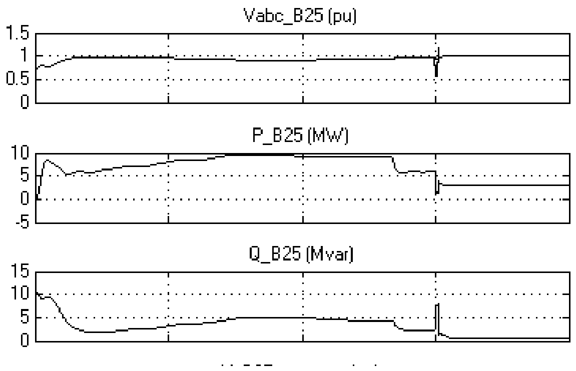

Fig.8(b)

7.2 Response of system with DSTATCOM

when the wind speed is varied from (8-11)m/s ,with DSTATCOM the output active power for each pair of turbine is 3MW , observed reactive power for each pair of turbine Reaches 1.47Mvar, turbine speed for each pair of turbine Reaches to 1.0045pu as shown in fig 9 9(a). with respect to 25KV bus voltage rises to 0.998 pu and no variation of active and reactive power at 25 kv bus as shown in fig 9.1.

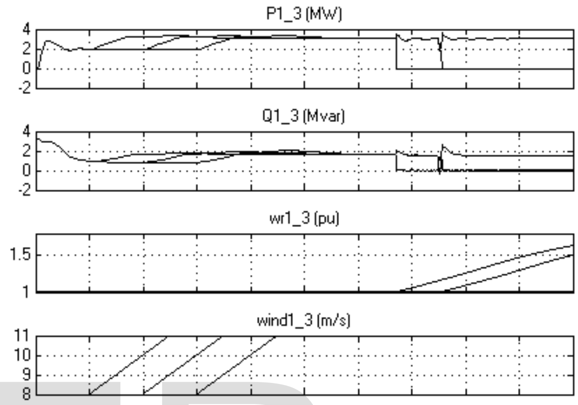

Fig. 9(a)

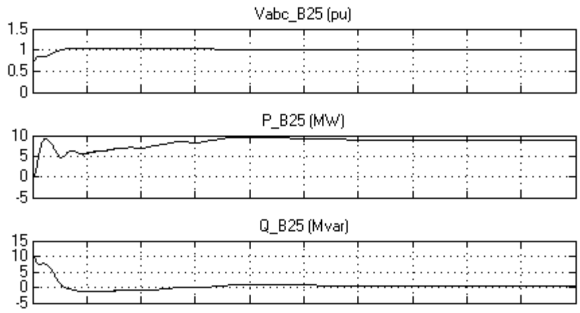

Fig.9(b).

8. CONCLUSION

The electrical output power generated from wind t sources of energy is variable in nature and hence, efficient power control is required for these energy sources. When a wind farm is connected to grid, it is necessary to provide efficient power control during normal operating conditions Voltage instability problems occur in a power system that is not able to meet the reactive power demand This paper explores the possibility of connecting a STATCOM to the wind power system in order to provide efficient control. In this work, the wind turbine modelled is a SCIG that is an induction machine which requires reactive power compensation during grid side disturbances. An appropriately sized STATCOM can provide the necessary reactive power compensation when connected to grid. Also, a higher rating STATCOM can be used for efficient voltage control and improved reliability in grid connected wind farm.

A.System parameters

(Table 1 Wind turbine induction generator)

Rated power(MVA)	9
Rated voltage (v)	575
Stator resistance(pu)	0.004843
Stator inductance (pu)	0.1248
Rotar resistance (pu)	0.004377
Rotar inductance(pu)	0.1791
Magnetizing inductance(pu)	6.77
Pole pairs(p)	3

(Table 2 STATCOM)

Converter rating(MVA)	3
System voltage (Kv)	25
Converter resistance(R)	0.22/30
Converter inductance(pu)	0.22
DC link capacitance(pu)	40000/10

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