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Paralleling Modeling of STATCOM and Wind Farm in Transmission Line using MATLAB and Analysis of Bus Voltage

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***Abstract*: The concept of Var compensation embraces a wide and diverse field of both system and customer problems, especially related with power quality issues, since most power quality problems can be attenuated or solved with an adequate control of reactive power. In general, the problem of reactive power compensation is viewed from two aspects: load compensation and voltage support. Static voltage instability is mainly associated with reactive power imbalance. Thus, the load ability of a bus in a system depends on the reactive power support that the bus can receive from the system. As the system approaches the maximum loading point or voltage collapse point, both real and reactive power losses increase rapidly, therefore the reactive power supports have to be locally adequate. With static voltage stability, slowly developing changes in the power system occur that eventually lead to a shortage of reactive power and declining voltage. The Flexible AC Transmission System (FACTS) technology is a promising technology to achieve complete deregulation of power system based on power electronic devices, used to enhance the existing transmission capabilities in order to make the system flexible and independent in operation then the system will be kept within limits without affecting the stability. Increased transmission demand is met where possible by increasing the existing transmission capacity. When trying to improve the transmission capacity, a key assumption is made that if the overall system reliability is not improved, at least the existing system reliability is maintained. The research work in this work is focused on FACT'S Controllers.**

***Keywords*: Flexible AC Transmission System, variable-speed wind turbine, rotor-side converter, grid-side converter, doubly fed induction generator, Static Synchronous Compensator, phase-locked loop.**

1. Introduction

The worldwide concern about environmental pollution and a possible energy shortage has led to increasing interest in technologies for the generation of renewable electrical energy. Among various renewable energy sources, wind power is the most rapidly growing one in Europe and the United States. With the recent progress in modern power electronics, the notion of a variable-speed wind turbine (VSWT) equipped with a doubly fed induction generator (DFIG) is receiving increasing attention because of its advantages over other wind turbine generator notions. In the DFIG notion, the induction generator is grid-connected at the stator terminals; the rotor is connected to the utility grid via a partially rated variable frequency ac/dc/ac converter (VFC), which only needs to handle a fraction (25%–30%) of the total DFIG power to achieve full control of the generator. The VFC consists of a rotor-side converter (RSC) and a grid- side converter (GSC) connected back-to-back by a dc-link capacitor. When connected to the grid and during a grid fault, the RSC of the DFIG may be blocked to protect it from over current in the rotor circuit. The wind-turbine typically trips shortly after the converter has blocked and automatically reconnects to the power network after the fault has cleared and the normal operation has been restored.

Wind power is the use of air flow through wind turbines to provide the mechanical power to turn electric generators. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land [3]. The net effects on the environment are far less problematic than those of non-renewable power sources.

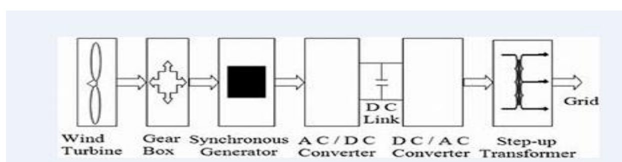

Fig. 1. Wind energy system

2. Static synchronous compensator (STATCOM)

A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks.[1][2] SVCs are part of the Flexible AC transmission system [3][4] device family, regulating voltage, power factor, harmonics and stabilizing the system. A static VAR compensator has no significant moving parts (other than internal switchgear). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks.[5] The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations:

- Connected to the power system, to regulate the transmission voltage ("Transmission SVC")
- Connected near large industrial loads, to improve power quality ("Industrial SVC").

A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; conversely, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power [5]. The response time of a STATCOM is shorter than that of a static VAR compensator (SVC) [6], mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage).

A static var compensator can also be used for voltage stability. However, a STATCOM has better characteristics than an SVC. When the system voltage drops sufficiently to force the STATCOM output current to its ceiling, its maximum reactive output current will not be affected by the voltage magnitude. Therefore, it exhibits constant current characteristics when the voltage is low under the limit. In contrast the SVC's reactive output is proportional to the square of the voltage magnitude. This makes the provided reactive power decrease rapidly when voltage decreases, thus reducing its stability. In addition, the speed of response of a STATCOM is faster than that of an SVC and the harmonic emission is lower, however STATCOMs typically exhibit higher losses and may be more expensive than SVCs, so the (older) SVC technology is still widespread.

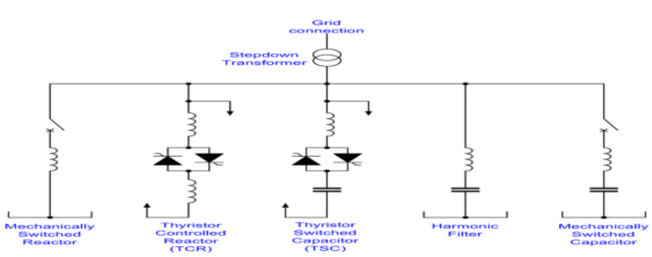

Fig. 2. Static var compensator

3. Objectives

The wind turbine that using squirrel cage induction generator needs more studies about its performances when it is connected to the grid to discuss the issues that accompany its normal operation to get better performance of it, therefore the objectives of this work are studies.

The main objectives of this work are:

1. Facilitate continuous operation of wind turbines during disturbances.
2. Stability further (during grid faults)
3. Proper reactive power compensation by using STATCOM.

4. FACTS Technologies

A. *Series Compensation*

Series compensation is the technique of improving the system voltage by connecting a capacitor in series with the transmission line. In other words, in series compensation, reactive power is inserted in series with the transmission line for improving the impedance of the system. It improves the power transfer capability of the line. It is mostly used in extra and ultra-high voltage line. Series compensation has several advantages like it increases transmission capacity, improve system stability, control voltage regulation and ensure proper load division among parallel feeders.

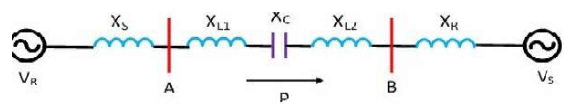

Fig. 3. Series compensator

B. *Shunt compensation*

In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

1) Shunt capacitive compensation

This technique is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is further in power factor.

2) Shunt inductive compensation

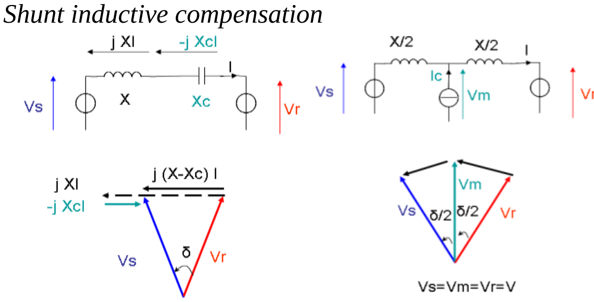

Fig. 4. Series and Shunt compensators

This technique is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load – very low current flows through the transmission line. Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line. The power transfer capability is thereby increased depending upon the power equation.

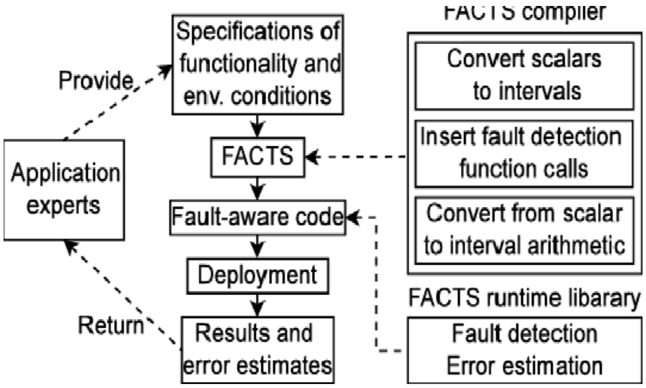

Fig. 5. Overview of FACTS

5. Modeling and simulation results

The investigated power system network is modeled and simulated in MATLAB / SIMULINK as shown in Fig. 5 and Fig. 6 to study the steady state behavior with SVC and STATCOM. The fault is initiated between 10 and 10.1 sec from starting of the simulation. The purpose of running simulation in this mode is to verify the dynamic reactive power compensation capability of STATCOM during the event of fault, while integrating wind power in a distribution network. The network consists of a 132 kV, 50 Hz, grid supply point, feeding a 33 kV distribution system through 132/33 kV, 62.5 MVA step down transformer. There are two loads in the system; one load of 20 MW and another load of 4 MW at 50 Km from the transformer. The 33 kV, 50-kM long line is modeled as line. A 9 MW wind farm consisting of six 1.5 MW wind turbines is to be connected to the 33 kV distribution network at 4 MW load point. Dynamic compensation of reactive power is provided by a STATCOM located at the point of wind farm connection. The 9 MW wind farm have conventional wind turbine systems consisting of squirrel-cage induction generators and variable pitch wind turbines. Each wind turbine has a protection system monitoring voltage, current and machine speed. Test system is simulated in MATLAB/Simulink. Fig. 5 and Fig. 6 shows the Simulink model of the test system. Phase simulation is used to simulate the test system; so as to make it valid for intended purpose. Variable-step ode23tb solver is used for simulation. The simulation time is 20 sec. The total MVA loading on the system is 50 MVA; considering the T & D losses in the system it is over loaded and representing weak distribution network. Dynamic compensation of reactive power is provided by a STATCOM located at the point of wind farm connection.

The simulation is run in three different modes, as follows:

1. without Wind Farm and STATCOM,
2. with Wind Farm and without STATCOM,
3. with Wind Farm and STATCOM

A. *Simulink and result*

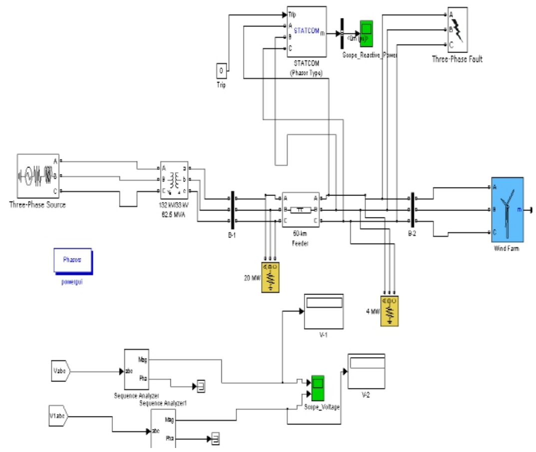
Fig. 6. Simulink model


Fig. 7. Simulink result

6. Conclusion

For the proposed work stability further of wind generation system using induction generators is investigated. The wind farms supply the active power to the grid when the wind turbines are connected to the grid, but at the same time, the reactive power is absorbed from grid. Induction machines are mostly used as generators in wind power based generations. Without reactive power compensation, the integration of wind power in a network causes voltage collapse in the system and under-voltage tripping of wind power generators. Therefore, it is necessary to compensate the reactive power for grid-connected wind farm to eliminate the effects of voltage fluctuations which is caused by reactive power loss in grid. With the rapid development of power electronics technology, traditional reactive power compensation shows some obvious drawbacks and connecting the Flexible AC Transmission System (FACTS). STATCOM is proposed in this study to compensate the reactive power & improve the stability of the system.

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