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Analytic Approach to Smart Grid: Active Power and Frequency -A Review

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ABSTRACT
Grid Integration and Grid Management, in conjunction can bring about a tremendous change in the way electricity is generated and consumed. Smart Grid uses two-way flow of electricity and information to create an automated energy delivery network, it is even regarded as the next generation power grid. In this paper, a Smart Grid has been designed by MATLAB simulation approach for synchronization of two power plant and for analysis of active power and grid frequency. Using active power and frequency of grid, helps in analysing the range of maximum permissible loads that can be connected to their relevant bus bars.

Keywords
Smart Grid, MATLAB, Active Power, Frequency

1. INTRODUCTION
Smart grids are modernized electricity grids that integrate information technology and communications infrastructure to provide greater transparency on electrical energy use and to improve the quality of energy supply. Grid Integration and Grid Management, in conjunction can bring about a tremendous change in the way electricity is generated and consumed. Smart Grid uses two-way flow of electricity and information to create an automated energy delivery network, it is even regarded as the next generation power grid. Smart grid is technically classified in three categories namely Smart Infrastructure System, Smart Management System and Smart Protection System [2]. The simulation works of this paper is done under the Smart Infrastructure System. The main parameter in any power system network to show stability is active power and frequency.

In today's power system network, distributed and conventionalgeneration are combined used to control the power flow in order to get a highly stable network. The smart grid model will be including 4 units of Thermal power plant (conventional generation) and 6 units of Wind power plant (distributed generation). The wind power plant is connected to major load side to control the power flow and this connecting point is treated as smart grid. Synchronous Generator is used to generate power in Thermal power plant and in Wind power plant Doubly Fed induction generator (DFIG) [9]. The overall Frequency of system is controlled by controlling the frequency of both synchronous generator and DFIG independently. The model simulates the power system network with two area system control where each area is characterized with two conventional thermal power plant each having 900 MWcapacity.

2. CONTROL METHOD
Active power and frequency analysis process and control of this power system is explained by two ways and they are as:

(i) By Automatic load frequency control (ALFC) loop of synchronous generator and measuring active power values at each individual busbar.

(ii) By Automatic frequency control of doubly fed induction generator and measuring active power values at each individual busbar.

(iii) By using FACTS devices.(Statcom)

2.1 Frequency And Power Analysis of Conventional Grid

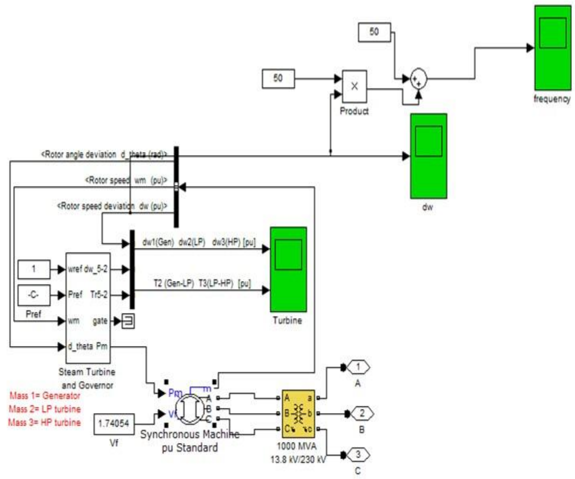

Fig 1: Block Diagram Of Synchronous Generator

Depending upon the load angle gradient the flow of real power takes place from source to load or from one area to another area. As the loads are increasing or decreasing then frequency will decrease or increase accordingly. For automatic frequency control, in both single and double area loop ALFC is used.

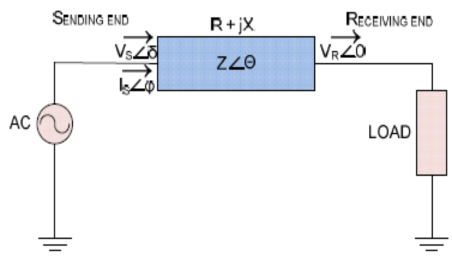

Fig 2: Single Line Diagram

Automatic frequency control loop (ALFC) can be used for frequency control in thermal power plant, which comprises generator, load, prime mover and governor.

The steam input of governor system is adjusted with respect to turbine speed which is proportional to load variation. As the change in the value of speed reduces, the error signal becomes smaller and the position of the governor and fly balls come closer to the point, required to maintain the constant speed. One way to restore the speed or frequency to its value is to add an integrator on the way. The integrator unit will monitor the average error over a period of time and will get the better offset. Thus as the load of the system varies continuously, the generationis adjusted automatically to restore the frequency to the normal value. This is known as Automatic Generation Control. In an interconnected system, the role of the AGC is to divide the load among the system, stations and generators so as to achieve maximum economy and reasonable uniform frequency.

When a group of generators are closely coupled internally and swing in unison, the generator turbines tend to have the same response characteristics. Such a group of generators are said to be coherent. It is assumed that the ALFC loop represent the complete system and the group is called the control group. In a two area system, during normal operation the real power transferred over the tie line is given by

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} Sin\ \delta$$

Where $X_{12} = X_1 + X_{tie} + X_2$

And $\delta_{12} = \delta_1 - \delta_2$

For a small deviation in the tie-line flow

$$\triangle P_{12} = \left.\frac{dP_{12}}{d\delta_{12}}\right| \triangle\delta_{12} = P_s \triangle\delta_{12}$$

$$\triangle P_{12} = P_s \ (\triangle\delta_1 - \triangle\delta_2)$$

Where

P_{12}=powerflowbetweenarea1andarea2.

E_1 = generated voltage of area 1.

E_2 =generated voltage of area 2.

X_{12} = reactance between area 1 & area 2.

X_1 = reactance of area 1.

X_2=reactance of area 2.

δ_1 =load angle of area 1.

δ_2 =load angle of area 2.

δ_{12} = load angle between area 1 & area 2.

The tie-line power deviation then takes on the form

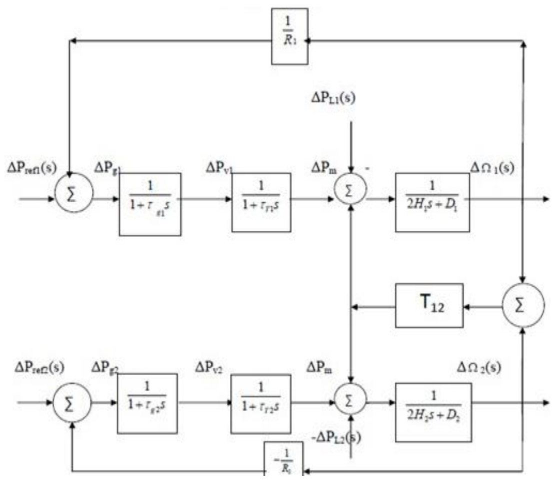

Fig.3: Representation Of Tie Line Power

2.2 Frequency Control of DFIG

Doubly-fed electric machines are basically machines in which alternating currents are fed into both the stator and the rotor windings. They allow the amplitude and frequency of their output voltages to stay at a constant value, no matter the speed of the wind blowing on the wind turbine rotor. Because of this, DFIG can be directly connected to the ac power network and remain synchronized with the ac power network.

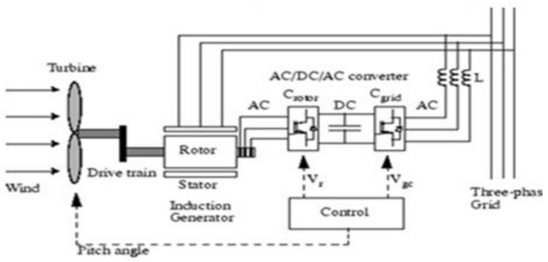

Fig 4: DFIG System

When the magnetic field of the rotor rotates in same direction as the generator rotor, the speed of rotor$n_{rotor}$and the speedof the rotor magnetic field$n_{\phi,rotor}$ (proportional to f_{stator}) add up. The frequency of the voltages developed across stator windings of the generator can thus be calculated using the following equation:

$$f_{stator} = \frac{n_{Rotor} \text{ x } N_{Poles}}{120} + f_{Rotor}$$

Where

f_{stator}= frequency of the voltage induced across the stator winding

and

f_{rotor} =frequency of the ac currents fed into DFIG

Conversely, when the magnetic field ofthe rotor rotates in the direction opposite of the generator rotor, the frequency is calculated using

$$f_{stator} = \frac{n_{Rotor} \text{ x } N_{Poles}}{120} - f_{Rotor}$$

2.3 FACTS Devices

FACTS are represented by a group of power electronic devices. This technology was developed to perform the same functions as traditional power system controllers such as tap changer transformer, phase shifting transformers, reactive passive compensators, synchronous condensers, etc. Particularly FACTS devices allow controlling all parameters that determine reactive and active power transmission.Replacement of the manual switches by semiconductor switches allowed much faster response times without the need for limiting number of control actions. However, FACTS technology is much more expensive from the mechanical one. FACTS devices isdivided into two generations. Older generation based on the thyristor valve, where newer use Voltage Source Converters (VSC). In both categories there are corresponding devices that perform similar services.VSC technology offers faster control over a wider range. Moreover, new generation don't need bulky reactors, thus size of these devices is considerably smaller than the thyristor controlled ones. However,VSC technology requires use of self commutating semiconductor devices which is more expensive, have higher losses and smaller voltage ratings when compared to the thyristors. FACTs devices can also be categorized by the way they are connected to power systems shunt, series or shunt series connection. The purpose of shunt devices is to provide reactive power compensation and dynamic voltage support to the lines or loads. Static VAR Compensator (SVC),can be seen as a variable susceptance with a smooth control over a wide range from capacitive to inductive . It is the oldest FACTS device and has the biggest number of applications. STATCOM is another shunt connected device, which behaves like a synchronous voltage source which can inject or absorb reactive power. Biggest advantage of STATCOM over SVC is the ability to maintain the reactive current output at its nominal value over a large range of node voltages, where SVC has limited current capability when voltage is reduced.

A. Static Synchronous Compensators(STATCOM)

The STATCOM system is one of the FACTs devices used for the integration of wind farms with Grid to improve the transient and steady state stability of the power system. STATCOM injects or absorbs reactive power to or from the grid to compensate small voltage variations at the connection point of the wind farm with the grid. STATCOM is also used when a voltage dip occurs. Many studies show that STATCOM helps the wind farm to stabilize voltage especially after a voltage dip occurs.

According to the IEEE, STATCOM system is a static synchronous generator operated as a static compensator connected in parallel whose output current (inductive or capacitive) can be controlled independently of the AC system voltage. A charged capacitor acts as a source of dc. This current feeds an AC/DC power converter, which produces a set of outputs with controllable three-phase voltages. Also, the frequency of these voltages istheACsystemfrequency.Since theAC/DCpowerconverteris controlled by PWM techniques, so the output voltages achieved are practically sinusoidal. This controlling is possible by the high switching frequency of the IGBT, GTO, IGCT or IEGT transistors of the power converter.

The system is characterized by a rapid time response and its ability to provide a control voltage to the connection point through reactive power compensation. It can be used for filtering harmonics, improving transient and dynamic stability, dynamic over voltages and under voltages,voltage collapse, steady state voltage, excess reactive power flow and undesirable power flow .This enables the wind farm, for instance, to have a better response in voltage drop as well as more stable system. Usually, STATCOM is installed at the MV bus in the wind farm. Its aim is to help the wind farm in situations of voltage drop, voltage regulation, power factor control and power flow stabilizing .

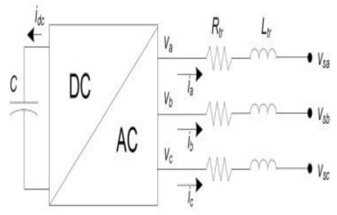

Figure 5. Schematic of STATCOM

The operating principle of STATCOM as shown in figure.

If V=Vs (pu values), no current flows through Rtr and Ltr. IfV>Vs,current ows through RtrandLtr.As the impedance is essentially inductive, the current phasor is perpendicular to Vs and V voltages. STATCOM injects reactive currentto the grid (Capacitivecurrent).

If V<Vs,current flows through RtrandLtr.This time the current flow is opposite to the previous,which implies that STATCOM absorbs reactive power from the grid.

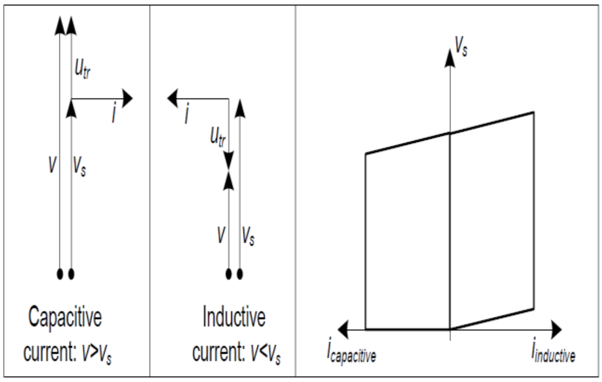

Figure 6. Operating principle of STATCOM

STATCOM reactive current is determined by the difference between grid voltage and power converter voltage.Reactive currentisnot dependentofthevoltageoftheconnectionpoint of STATCOM and is limited by the capacity of the power converter and grid voltage variation. The operation area of STATCOM is determined in figure 2. The maximum inductive current is not assumed until a certain lower limit of the voltage. This is because the voltage drops across the coupling transformer as shown in figure 3. The STATCOM control system, d-q reference is possible to control d-qcurrent independent of DC voltage and reactive power of STATCOM. The calculation of Re-active Power related to STATCOM DC voltage are expressed Q = -V2 B + kVdc VB cos(θ - α) – kVdc VG sin(θ - α) Here, V is the transmission voltage, B is the suseptance, k the modulation index, Vdc the capacitor voltage, alpha the thyristor firing angle, θ phase angle of the transmission line, G is the admittance of coupling transformation.

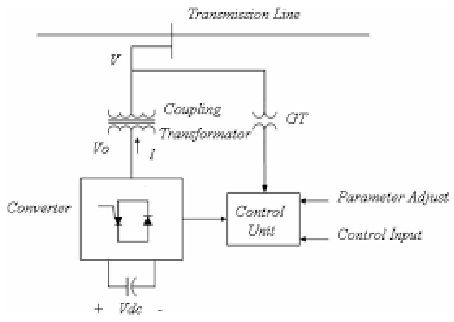

Fig7. Systematic of STATCOM

2. CONCLUSION

In this paper three controlling methods for frequency and active power analysis for smart grid has been studied. Out of these three methods, the DFIG method is best for controlling the above parameters but its initial cost is high as compared to other controlling methods discussed in this paper.The simulation works of this paper is done under the Smart Infrastructure System. The main parameter in any power system network to show stability is active power and frequency.

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