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Minimization of Fluctuation of Wind Power and Control in Smart Grid with Distributed Generation

Govinda,
M.Tech.(Control System)
Electrical Engineering Dept.
NIT Patna, Bihar

Chandan Kumar Sinha,
M.Tech.(Power System)
Electrical Engineering Dept.
NIT Patna, Bihar

Prof. Rajib Kumar Mandal
Electrical Engineering dept.
NIT Patna, Bihar

***Abstract*— In our environment there is always presence of wind due to temperature and pressure difference in different part of the earth. Wind cut off and tower shade are source for power variation of grid connected wind turbine during continuous working. The innovative idea for the minimization of fluctuation of wind power is active current control of DFIG is projected. It flatten generator output active power oscillations by adjusting active current of the DFIG. We know that power is in the form of kinetic energy of the wind and wind kinetic energy is converted into rotational kinetic energy of the wind turbine. As wind speed varied kinetic energy also varied so wind power fluctuating. For controlling the wind power variation there is few special methods is used. One of which is vector control. In vector control there is transformation of 3- Φ current in two orthogonal axes. This is done using way given by Clark and Park. PI controller is also used for the controlling the system. In fact it is used for regulation of power. For controlling the variation of power inverter is used on both side rotor side and grid side. With the assist of converter reactive power is set to zero so PF of the system becomes unit. So current through converter is under decrement so charge for converter also reduced.**

Keywords— Doubly fed induction generator(DFIG), PI(proportional and integral), vector control, active current

I. INTRODUCTION

Wind energy is most hopeful nonconventional energy resource there is always several problem with other type of conventional energy resource. This is because of energy demand increment and environmental pollution. With increment of the capability of wind turbine, wind power access to the grid increases day by day. Wind turbine on the power value become very important issue. Grid attached variable speed wind turbines are varying source of power in nonstop working. The power variation is normally referred to as the 3-Φ oscillation. It is due to wind speed variation, wind cut off and tower shade effect. Therefore the output power will under decrement 3 times per revolution for 3 bladed wind turbine. "Kinetic energy of the wind is used to spin the generator of the wind turbine to generate electricity." There are a number of factors which add to the efficiency of the wind turbine for extract the power from the wind. Wind variation is very obvious in earth environment. Due to this wind speed is key point for attaining power and deciding the type of system. At first with wind speed is also the significant factors in shaping how the power can be extracted from the wind. . After that there is thinking of turbine which is used for extracting power from wind. So the next significant factor is wind turbine's rotor blade. Length of rotor blades of the wind turbine is also an significant aspects of the wind turbine because power production from wind is also relative with the swept area of rotor blades which is the square of the swept area. In somewhere there is some other methods also used for minimizing the variation of wind power. This is used for the turbine which is connected to the grid. Pitch control is used to diminish the power variation in [1]. But control formulation is rather complex. Reactive power recompense is commonly used technique. However, the way shows its limits, when grid impedance angle is low in some distribution network in [2]. Vector control techniques are mainly common for DFIG based wind turbine system. There are 2 vector control in both side. One is for rotor side converter and other is for grid side converter. Purpose of rotor side converter is to attain maximum power by controlling active current of DFIG. On the other hand principle of grid side converter is to attain constant dc link voltage. For reducing current in rotor side converter and grid side converter value of reactive power of grid side converter and rotor side converter are position to 0 which is for unit PF operation. Also the active power control by varying DC link voltage of the back to back converter is presented to attenuate the power variation in [3]. But the giant DC link capacitor is necessary in this way due to storage space for the rise and fall in power in DC link.

II. WIND POWER

Due to wind speed there is kinetic energy in the wind. This kinetic energy of the wind is converted into rotational energy of turbine which is responsible for generation of power in wind power system. Actually wind speed is used for twisting the wind turbine. There are several factors which is affecting the wind power generation. They are wind speed, length of rotor blade, air density, turbine swept area. Wind power is on relation with cube of wind speed which means that if the wind speed becomes 2times larger than earlier then the power generate will be increased by 8 times to the original power. So the value of wind speed is very important in wind power

generation. And wind speed is dependent on site of wind farm. So site of wind farm shows very significant role in order to wind turbine to extract utmost attainable power form the wind. As wind is twisting the wind turbine rotor blade it cuts wind area so the swept area of the wind turbine is also important factor in wind power generation. This area is depending on length of wind turbine rotor blade. If rotor blade is larger this area is larger so generated power is larger and if rotor blade is smaller then swept area is smaller. So length of rotor blade should be larger but there should be mechanical strength in rotor blade which can give optimal power. With the recent advance in fiber glass techniques there is possibility of making very large rotor blade in order of 20-30 m.

So we have

$$P = C_p(\lambda, \beta)\frac{\rho}{2}A\upsilon_{wind}^3$$

$$\lambda = \frac{W_r R}{\upsilon_{wind}}$$

Where

P - Turbine mech. output power.

C_p - Performance coefficient of the turbine.

ρ - Air density.

A - Turbine swept area.

υ_{wind} - Wind speed.

λ - Tip speed ratio of the rotor blade tip speed to wind speed.

β - Blade pitch angle.

W_r - Angular speed of rotor.

III. WIND TURBINES

There are mainly two types of wind turbine with respect to their rotor settings. They are:

- Horizontal-axis rotors and
- Vertical-axis rotors.

As rotor of wind turbine access by wind is supposed of horizontal-axis. In this type wind turbine rotor blades are rotating due to wind and it is placed in front of tower and axis of rotation is parallel to the wind direction. When rotor blades are in front of tower then it is known as upwind type. When rotor blades are in back of tower then it is known as downwind type. Normally we are using only upwind type in high power generation.

The main components of a wind turbine is classified as (i) Tower (ii) Rotor (iii) Generator (iv) Yaw (v) Control system and (vi) Braking and transmission system.

IV. DOUBLY FED INDUCTION GENERATOR

It is mostly used in wind turbines. Doubly fed induction generator based on an induction generator having multiphase wound rotor and multiphase slip ring assembly having brushes for accessing the rotor windings. But in slip ring assembly there is some problem with efficiency, cost and size. Thus brushless wound rotor induction generator is better option.

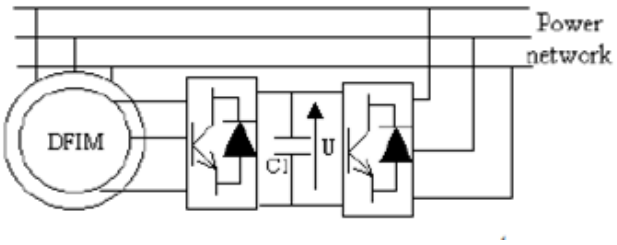

Figure 1 DFIG

Rotor winding of DF induction generator is connected to the grid via slip rings and for controlling rotor current and grid current back to back voltage source converter is used. so rotor frequency and grid frequency can differ independently. Due to the rotor current controlling with converter the adjustment of the active reactive power is possible which is given via grid trough stator and also independent to the generators turning speed. Usually two types of controlling method is used one is two axis current vector control and other is direct torque control.

V. WIND TURBINE MODEL

Modelling of wind turbine comprises of wind turbine, doubly fed induction generator, gear box and back to back converter which is composed of grid side converter and rotor side converter and a large capacity dc link capacitor as for energy storage placed in between the two converters. For showing turbulent speed of wind there is use of look up table in MATLAB. Doubly fed induction generator, the controller and the power system are modelled using simulation blocks.

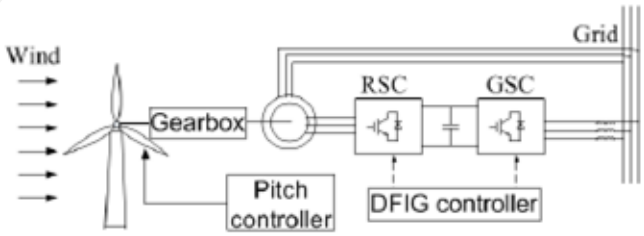

Figure 2 Wind turbine model

VI. SMART GRID

The successful coordination of generation, transmission, distribution and users through the modern information and communication technologies is the basis of smart grid development.

In smart grid system data is collected in such a manner that it can transform in useful information. That transformed data is useful for decisions support of power system operation. In smart grid type of fault and its position can efficiently identified. This is possible due to the modern information technology and communication system. That is why modern control system and information technology is key factor for smart grid.

VII. DISTRIBUTED GENERATION

In distributed generation the network is used for generation system as well as distribution system. There may be a solar system or wind system which is used for generation and power of these system connected to grid and then distributed to the load. When grid is used in islanded mode then conventional power generation is disconnected to the grid and only small or independent electric network is used for load.

Distributed generation is good concept for the load when load is far away to city because in distributed generation system supply can be taken in islanded mode and it can also taken from grid. When load is very few then it can work in islanded mode and when load is high then it can work as grid connected mode.

VIII. BASIC CONTROL SCHEME

There are mainly two modes for controlling the variable speed wind turbines. When the wind speed is above the upper limit and below the lower limit the purpose of controlling is to attain maximum power. Wind turbine control has purpose to continue to have optimal tip speed ratio in such a way that maximum wind power attained. When wind speed becomes larger than rated wind speed the controlling purpose is to maintain the power output constant at base value using pitch control. This is done for protection of the system in overloading.

Vector control techniques are most common for doubly fed induction generator based wind turbine system. There are two vector control in each side. One is for rotor side converter and other is for stator side converter. Purpose of rotor side converter is to attain maximum power by controlling active current of doubly fed induction generator. On the other hand purpose of grid side converter is to attain constant dc-link voltage. For reducing current in rotor side converter and grid side converter value of reactive power of grid side converter and rotor side converter are set to zero which is for unity power factor operation.

IX. SPACE VECTOR PW MODULATION

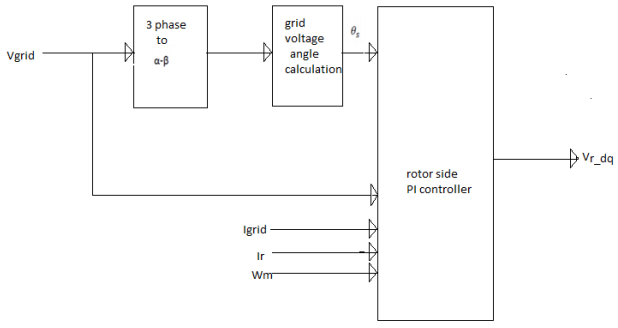

Figure 3 space vector control

In space vector PW modulation there is corresponding gate drive for each PW modulation cycle. A 3 Φ, 2 level inverter with dc link having 8 possibility for swiching that generates output voltage. So there is 8 voltage SV (U_0, U_1, U_2, U_3 upto U_7) .

X. SVM PWM CONTROL

In this controlling the output of PI controller is given to the vector controller which convert the direct and quadrature axes system into rotating α and β system and this further converted into a,b and c system using clark and park transformations.

Any 3 function of time in space vector satisfy

$$U_a + U_b + U_c = 0$$

The space vector modulation algorithm is based on principle of vector U^*.

$$U^* = \frac{2}{3}(U_a + a.U_b + a^2.U_c)$$

Where a= -0.5+0.866j

We can differ 6 sectors limited by eight discrete vectors U_0, U_1, U_2, U_3 upto U_7 .

$|U_0| = |U_7| = 0$ and U_1 to U_6 have same magnitude. They are 60 degree Φ shifted.

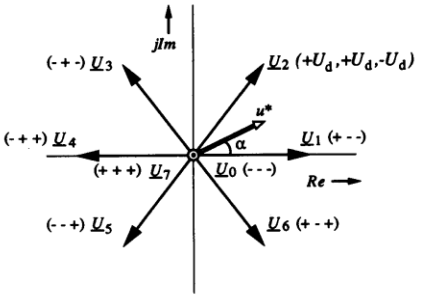

Figure 4 Spatial representations of vectors

$$U_a = \mathrm{Re}(U^*)$$

$$U_b = \mathrm{Re}(U^*.a - 1)$$

$$U_c = \mathrm{Re}(U^*.a - 2)$$

XI. CLARKS AND PARKS TRANSFORMATION

Clark and park transform is very important for space vector calculation of the system. From clark transform real and imaginary transformation can be implemented. Park transform is for transforming direct axis and quadrature axis current from stationary to moving reference frame. It is used for controlling the spatial relationship in stator current and rotor flux which is in space vector.

XII. RESULT AND DISCUSSION

Wind speed of the environment is always variable in certain limit in general. So for checking validity of the result the variable speed of wind is taken using different blocks of MATLAB. In figure shown below variable wind speed is taken from 11 m/s to 15m/s. With respect to time in second.

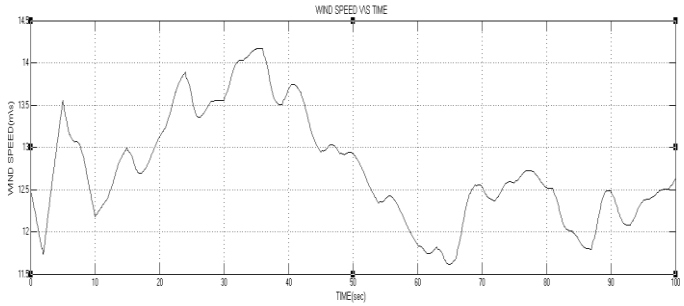

Figure 5 Wind speed

Wind speed is always vary but wind power can be obtained only at certain range. Except of that speed there is use of some controlling method which cut out the unwanted wind speed. Due to which power can be obtained at higher range.

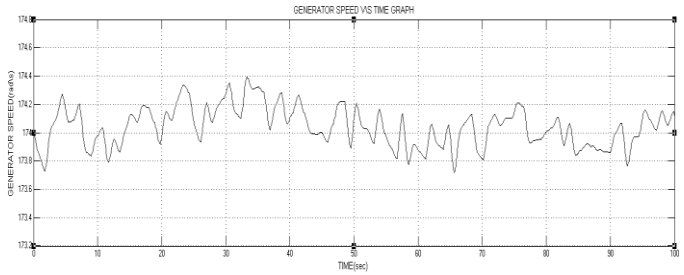

Figure 6 Generator speed

Generator speed is taken in rad/s with respect to sec. when wind turbine is connected to the induction generator than due to rotation of wind turbine rotor of induction generator also rotated. It is calculated in MATLAB using asynchronous machine block. Its speed is used for power calculation and controlling. When wind speed is impact on the turbine then it starts rotating. On its consequences rotor also starts rotating. But wind speed is variable so there is control in rotor side for smoothing the power output. For that converter is connected on rotor side.

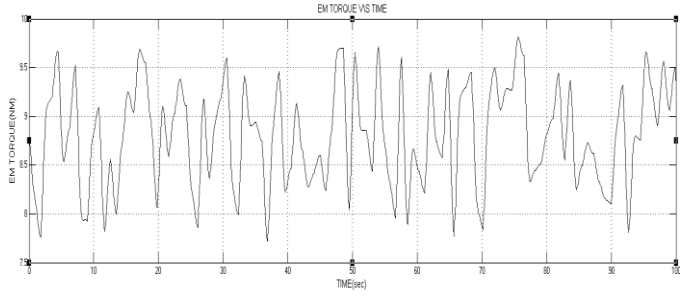

Figure 7 Electromagnetic torque

This is graph between electromagnetic torque generated by generator and time. This torque is taken in KNm with respect to time in sec. in accordance to the variation in wind turbine there is variation in electromagnetic torque of induction generator.

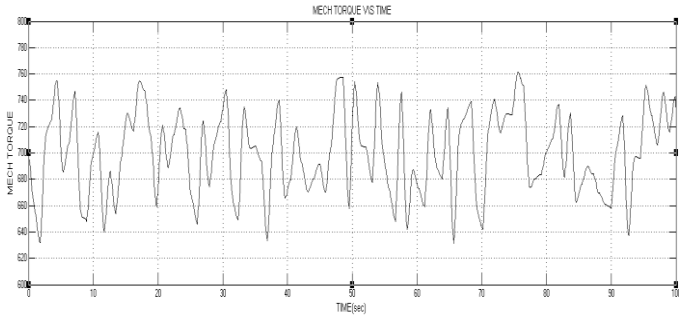

Figure 8 Mechanical torque

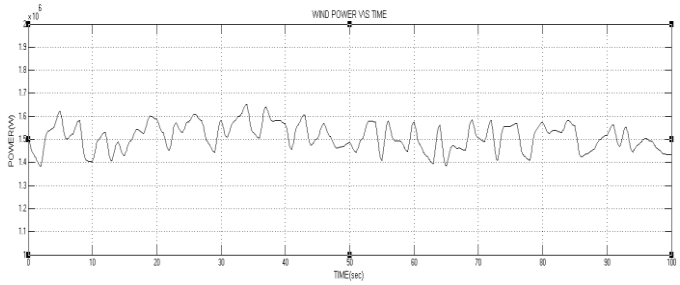

Figure 9 Wind power

The above graph is in between wind power and time. Wind power is power of induction generator. Power is taken in MW. It is in order of 1.35 to 1.65 MW. When wind speed is changes then power is also changes.

XIII. CONCLUSION

With help of MATLAB a MW doubly fed induction generator based on variable wind speed is studied. Active current control method is used to minimize wind power variation and control in smart grid with distributed generation. For controlling this there is also other controlling device such as PI controller vector controller and control through converter. There is also some transform that is Clark transform, park transform. Space vector controller is very important in this project because spatial vector transform the phasor quantity into different vector quantity and than controlling becomes more easier than phasor control. The above method of controlling is advantageous than previous method because previous method is for inertial control of wind turbine. So controlling was not able for the power quality. The method given in this thesis is very simple depending upon controlling of doubly fed induction generator using space vector control. We know that induction generator has need of reactive power for its starting so there is a problem of reactive power and this reactive power should come from the smart grid. So in induction generator there is no possibility of generation of reactive power. But in this control methodology there is use of grid side converter and rotor side converter which satisfy the need of induction generator however supply can be reactive as per need of induction generator. And output power can be reactive or active as per need of load. In this project for power quality improvement reactive power is set to zero with the help of PI controller and state vector control. So this methodology is simple and advanced.

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