Increasing Stability And Power Quality In Connection DFIG Wind Turbine To Grid By Using Battery Storage Source

Nasrin Sayahi

Abstract: One of the types of renewable energy, is the wind energy that has been caused using doubly fed induction generator (DFIG) widely. When the wind speed is lessor more than allowable range, wind turbine is isolating main Grid. And when the wind speed place in permitted range, it is connected to the Grid again. Reconnected Wind turbine to the main Grid cause that turbulences in the current and the output voltage of the generator and reduce power quality. In this paper, reconnected wind turbine to the main Grid is doing in presence battery storage source in order to increasing stability, reducing turbulences and increasing power quality. Battery storage source by control interface inverter, cause increasing stability, reducing turbulences and increasing power quality in reconnected wind turbine to the main Grid. Results of simulation confirm good and proper performance of battery storage source in reconnected wind turbine to main Grid.

Key words: wind turbine, DFIG, connect to Grid, power quality, battery storage source.

1 INTRODUCTION

Growing scarcity fossil fuels and pollutions, as a result of the use of these fuels, cause that have been increased using renewable energy such as wind power. Using wind energy to generate electrical energy began in America since 1925[1]. At that time used DC generators that connected battery chargers, to generate electrical energy. Since 1939 in America, formed AC Grid and fix speed synchronous generator was used to generate electrical energy from wind and decreased using of DC generators. Wind energy generated electricity from mid-1970, especially after a sharp rise in the price of fuel. In this decade, electrical energy production was did by fix speed synchronous generator but since the mid- decade 90 due to some advantages of induction machines compared to synchronous machines, the use of synchronous generators was decreased and induction machines was increased.[2-4] Between induction generators, doubly fed induction generators have better performance than others. For example, some benefits named, control active and reactive power, voltage control of Grid, frequency control in independent mode Grid and lack of need capacitor bank to supply required reactive power of induction generator [5]. When wind speed is out of range, wind turbines isolate Grid and by returning wind speed to allowable range, turbines connect to Grid again. During connection, occur a transition state that is turbulences of current and voltage very high and in addition to reducing power quality, can cause instability in the power system. In references[6-7] A method is provided based on design active and reactive power controllers its wind turbines that use interior turbine controllers to control oscillations but if the phase of turbine and main Grid voltage has high differences (requires high reactive power), this system is not responsive due to limit of turbine capacity. In reference[8] A method is presented based on implements fax that paid only to improve the voltage profile and increasing power quality, while severe frequency fluctuations will be created in current due to lack of injection reactive power. In this paper, It has been suggested a connection wind turbine to the main Grid with the battery storage source that at the time of reconnected wind turbine to the main Grid, the battery storage source using interface inverter controller, power be inject to the Grid and in addition to improving voltage profile and increasing quality power, damped current frequency oscillation quickly.

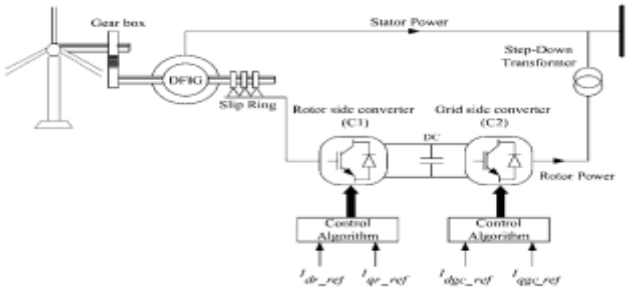

Fig. 1 *schematic of connected doubly fed induction generator to Main Grid*

2 WIND TURBINE

Due to variable wind speed, power generation by using wind energy accompany oscillation, It cause that many kinds of generator is using to generate power by using wind energy. One kind of wind generators, is DFIG that have ability to control them, efficiency of utilizing wind energy is very high. Generators (DFIG), due to the ability to control speed of the router machine, they are suitable structure for use in wind power plants. Usage DFIG is shown in figure 1. This system has an inverter/rectifier arrangement, that converter in the side of generator with slider rings connect to the three-phase rotor's windings and in principle, it is possible the performance of the high speed synchronous or under its speed synchronous. It is notable that router's converter acts as a variable frequency inverter in the speed under synchronous. Quite the contrary, the performance of its speed over synchronous, generate power and electric power from router is taken by slider rings that in that state, converter in the side of router acts as a rectifier. In this type of system, in addition to reducer transformer for level of distribution voltage, another

- *Nasrin Sayahi. Department of Electrical Engineering, Hakim Sabzevari University, Sabzevar, Iran E-mail: nasrin.sayahi1993@gmail.com*

transformer use to level of voltage the router winding and stator winding that which in turn require to additional circuit protection, this transformer helps to reduce ripple current in bridge. Some advantages of this model: 1) power that incurred converter, is the slip power that is a part of permitted total power. For example, if speed limit is 0.1 to 0.15 per-unit, permitted power converter will be only 0.1 to 0.15 per-unit of total power. 2) Due to power control in the slip frequency, response of this system is slower than synchronous generator system, but this state is faster than DC generator. 3) Harmonic: since the bridges only connect to slip power, harmonic currents decrease proportional to slip power and filter is easier. 4) Reactive power control: while active power is lag in this system, that is positive, a certain amount of reactive power require us to coordinate and angles of rectifier control and inverter. So performance with unity power factor, we can achieve continuously only using fixed capacitor bank and without switching capacitors. Mechanical power wind turbine that is actually a percentage of total power wind energy, calculate as below:

$$P_r = \frac{\rho}{2} A C_P(\lambda, \beta) V^3 \quad (1)$$

That ρ is air density, CP is power efficiency, λ is proportion edge speed, β is pitch angle, A is the swept surface by the router and finally V is wind speed. λ parameter define as below:

$$\lambda = \frac{\omega_r R}{V} \quad (2)$$

In which, R is radius of the router and is angular speed router. Due to parameters ρ and A are fix and also, we do not have wind speed, it is obvious from (1) that set the CP (that is function of two parameter β, λ) can control ρr desirably. We should explain when wind speeds higher than nominal speed, set CP through the parameter β and at wind speeds less than nominal speed, set CP through the parameter λ (of course in variable speed wind turbines). In [9], using numerical approximation methods, relationship CP and Parameters λ and β are obtained in closed form below.

$$C_P(\lambda, \beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3\beta - c_4\right)e^{\frac{-c_5}{\lambda_i}} + c_6\lambda \quad (3)$$

In which,

$$\lambda_i = \left(\frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}\right)^{-1} \quad (4)$$

In figure 2 is drawn feature CP according to λ and for different amounts β.

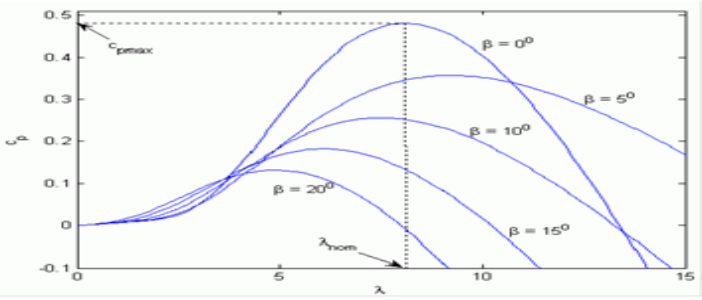

Fig. 2 *Characteristic power efficiency in terms of edge speed and for various quantities of pitch angle [9]*

2 BATTERY STORAGE SOURCE

Today in power systems with renewable sources, increased use of energy storage sources. This is due to increasing energy production from renewable sources (such as solar energy, wind energy, etc.) has not continuity. In the vicinity the system place a battery bank until at time reducing or lack of production power, be able to protect fed continuity. In the battery storage source, battery cells connect in series and parallel untill it reach standard level voltage of inverter and then to increase the capacity, strings connect in parallel. Battery bank by an inverter connect to the power Grid. When Grid is in normal mode and production power is more than consumable power, battery bank charge. And when production power decreases battery bank through the inverter to the power Grid, power be injected that by injecting active and reactive power, it can control in order frequency and voltage of Grid. An important discussion, in the design systems battery bank connected to the power Grid, is a design input and output filters inverter. This filter determines quality of delivered power to the power Grid so they should decrease oscillations of voltage and current proportion consumable power. In principles of inverter control should be noted that by controlling the output voltage's size and angle of the inverter in order can control active and reactive power.

3 Island mode and Grid connected a wind turbine has three functional state

Grid connection, Island mode and transient mode of Grid connected. Wind turbine has a property when the wind speed is lower than normal power generating, wind turbine separate Grid and production of power become zero, it means that separate Grid completely. For an example wind turbine in figure 3 when wind speed is of 15ms4, wind turbine is in Grid connection and wind turbine begin producing power and the power generation up to nominal speed (for example 15ms), using the controller of speed, do power injection, stabilize output voltage and frequency.

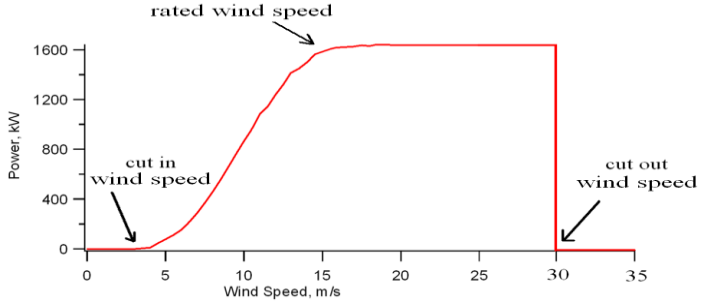

Fig. 3 *Curve of allowable working range of wind turbine based on wind speed.*

After the nominal speed, controller of pitch angle of wind turbine enters into orbit and rotation speed of router stabilize on the nominal speed of turbine. The control of pitch angle continue as far that wind speed does not reach destructive level and in case of cross limit, wind turbine enters into brake state and Island state. When wind speed is less than lower limit and more than limit, wind turbine separate Grid and until wind speed do not place in allowable range, wind turbine place separately Grid. If the wind speed place in the allowable range, wind turbine will connect to the Grid and power deliver to the power Grid. When wind turbine, from Island state changes to connected state to the Grid, then occures disturbance in the voltage and current that in case of lack of control, Grid can be unstable. By proper and quick injection power can minimize disturbances.

4 SIMULATION

In this paper, at first a sample Grid of reference [10] according to figure 4 is selected. As you can see in the study sample of a DFIG wind turbine is connected to the power Grid. Stators of the generator directly and its router by using electronic devices power are connected to the main Grid.

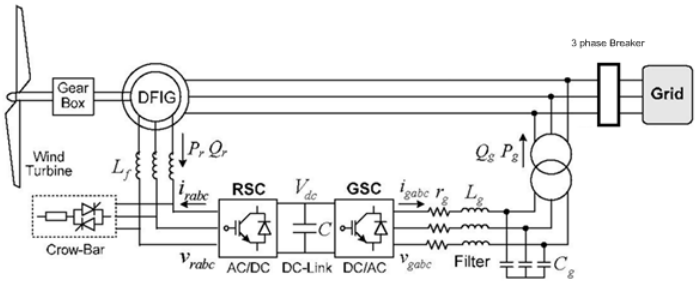

Fig. 4 *Schematic of simulated of connected wind turbine to the main Grid.*

In this paper, a battery storage source add to the suggested study sample until behavior of the DFIG wind turbine in the connected state to the Grid check carefully in the presence of battery storage source. Schematic of suggested system is shown in the figure 5. As see, a battery storage source is connected to the location of connected DFIG wind generator to the main Grid. The battery storage source by using an inverter and a power quality filter be injected power to the Grid.

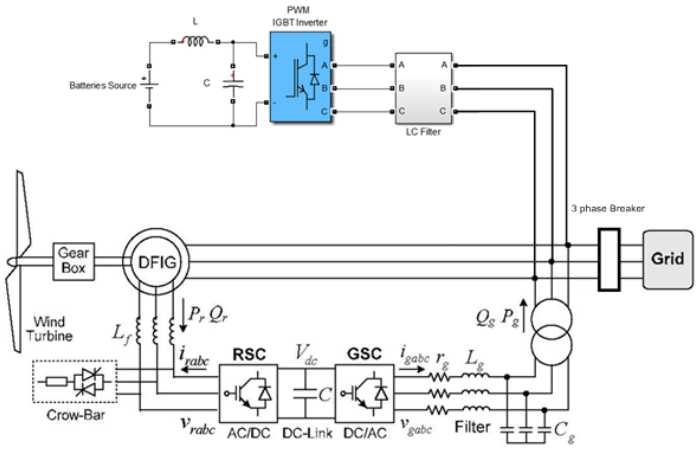

Fig. 5 *Schematic of simulated sample of connected wind turbine to the main Grid the presence of battery storage source.*

Section of power generation connected to the Grid that includes a wind turbine and a battery storage source connect to the Grid in a bus. When wind generator place outside the range of power generation, it separate main Grid by three-phase breaker and after a while if power generation is possible from wind energy, the wind generator will connect to the main Grid. When again wind generator connect to the main Grid, it cause fluctuations in current and voltage that decrease power quality. Due to climate change, the number of disconnect and connect to the Grid is seen a lot, due to wind generator connect to the main Grid again, amount of disturbances increases as same amount. Thus in order to increase power quality, a battery storage source placed along side turbine in the figure 5 that cause decreasing disturbances and increasing power quality. The figure 6, shows studies that simulated in MATLAB.

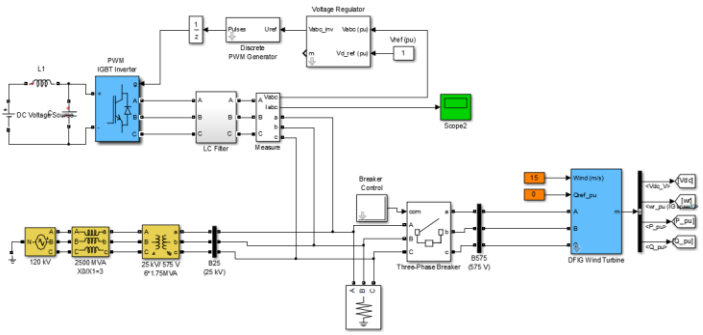

Fig. 6 *Simulation of connected wind turbine to the main Grid in MATLAB.*

When wind turbine connect to main Grid, battery storage source charge by receipt energy and in reconnected wind turbine to Grid, by power injection decrease power disturbances that cause increasing power quality. At first in this section, connected wind turbine alone to the main Grid is simulating and then the connection is simulating with the presence of battery storage source and then power quality investigate in two state. In the first state (that means connected wind generator to main Grid without battery storage source) wind generator connect to the Grid at the second one.

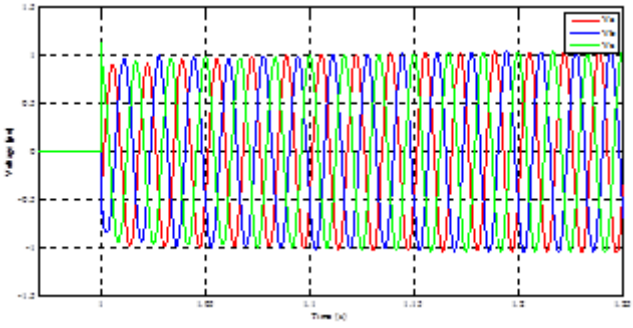

Fig. 7 *The voltage waveform in connected wind turbine to main Grid without battery storage source.*

Figure 7 shows the waveform of three-phase voltage double-faced of two-sided breaker that connect concurrently on the one hand to main Grid and on the other hand to wind generator. As you see in moment of connection, the voltage has disturbances thus it takes moments that voltage reach normal state. Figure shows waveform of current in the connection.

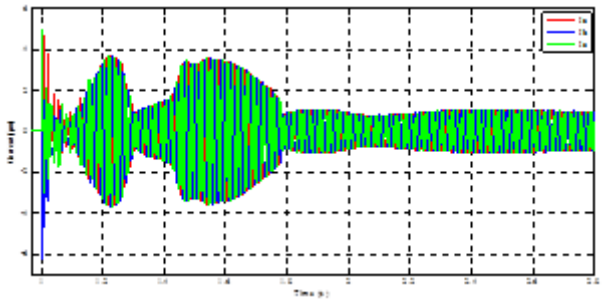

Fig. 8 *Waveform current in connection wind turbine to the main Grid without battery storage source.*

As you see, before second one, wind generator not inject any power to Grid and three- phase current has disturbances at the moment of connection. Current domain reach up to 6 times the amount per-unit and the current can endanger the stability of power system. Also in proportion takes a long time that reduce disturbances of current and reach normal situation.

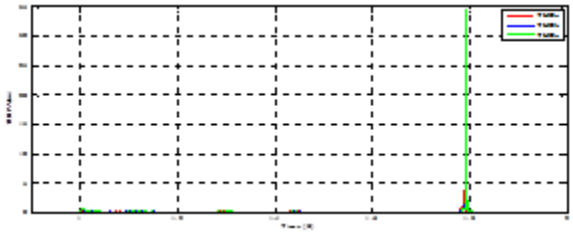

Fig. 9 *Curve of amount THD current in connection wind turbine to main Grid without battery storage source.*

In order to investigation stability of power system and power quality, total harmonic distortion (THD) for current of main Grid show in figure 9 that due to disturbances at the moment of connection, amount of THD is reached 35. And in this connection, power quality is reduced a lot and there is the possibility of instability in the system. The transient mode is due to reconnection wind generator to Grid. In the second case, connection of wind generator to Grid is in presence battery storage source. DC bus voltage of battery storage source changes AC voltage by a three-phase inverter and voltage and frequency of Grid control by power injection. In figure 10 the waveform of three-phase voltage has come in the second case the connection.

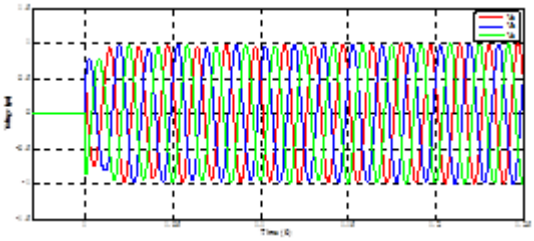

Fig. 10 *Waveform of voltage in connection wind turbine to main Grid in presence battery storage source.*

The voltage waveform in second case has less disturbances domain and as you see this disturbances damping quickly and three-phase voltage reaches normal state in less than a period. Inverter of battery storage source through its internal controller, in a way inject power that voltage disturbances are minimized. In figure 11 three-phase current waveform has come.

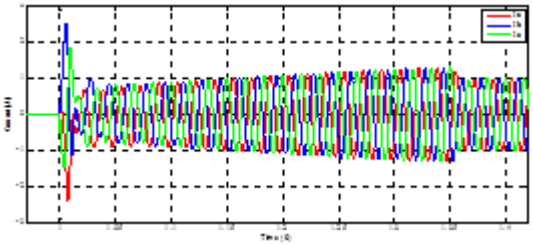

Fig. 11 *Current waveform in connection wind turbine to the main Grid in presence battery storage source.*

As you see, increasing current domain at the time of connection in the second case is up to 2.5 times of the per-unit amount. In means that in proportion to connection in the first case, amount of increasing of domain is decreased almost 60% . Also the current fluctuations is close to normal state and after 35% second, three-phase current reaches normal state.

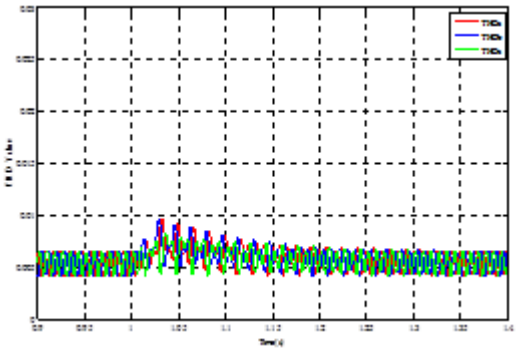

Fig. 12 *Curve of THD amount of current in connected wind turbine to the main Grid in presence battery storage source.*

Figure 12 shows total harmonic distortion for Grid current. As you can see, even in time of connection, the THD amount maximum is in allowable range, it means that, amount THD is less than 1% . Therefore connection in second case (with battery storage source), keeps the power quality in acceptable measure and while in first case (without battery storage source) THD amount for Grid current reaches 35. Above reaches shows that voltage storage source works well as a stabilizer of Grid parameters when connection wind turbine.

5 Conclusion

Reconnected main Grid is an important challenge in using doubly fed induction generator that cause disturbances in current and voltage, reducing power quality, reducing stability of system. In this paper, was suggested reconnected wind turbine to main Grid with power storage source, after simulation, you can see, that battery storage source can at time of reconnected wind turbine to Grid cause reducing disturbances in current and voltage, increasing power quality, increasing stability by the power injection through interface inverter. Results of simulation confirm the good and suitable performance battery storage source at time of reconnected wind turbine to main Grid.

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