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Performance improvement during grid fault in wind turbines using doubly fed induction generator

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ABSTRACT

Doubly fed induction generator (DFIG) has a vital role in wind turbines and their use is growing. The benefits are separate control reactive power, no need to compensator of reactive power, ability to function in a wide range of speed and having a small power electronic converters with capable of processing all generators active and reactive power. During an error in the network, to prevent the damages caused by passing high currents, converter cut the rotor-side in the DFIG. At this time, network-side converter loses its ability to supply the required reactive power and thus voltage stable and confirmation get in danger. In order to overcome this problem, benefices by using equipment's, such as STATCOM or SVC, provides the reactive power needs and embargo of cutting the wind farms from the network. Thus, the injection continuation of DFIG active power production will be established. Power electronic converters that usually used in the equipment structures of, STATCOM, SVC or even rotor-side converter and network in DFIG, often are voltage source inverters. This article theory is whether structure and capacity of the converter in DFIG is designed so that during causes error can enter the circuit as a STATCOM and take the charge of needed reactive power generation. Avoid the use of two transducers individually and by designing a converter with enough capacity, two types can be used, thus costs losses.

1. Introduction

Equipped turbines with doubly fed induction generator (DFIG) due to having the significant benefits used by many wind farms. This turbine is basically a variable speed turbine, comprising a rotor induction generator shunt winded that its stator directly connected to the network (load) and its rotor connected to the network via a back to back converter with DC link capacitive. Such structure with different frequencies can be fed up in bellow synchronic speed, causes electric power injected into the grid. Another advantage of this structure can be noted as a control capability of separate injection active and reactive power into the network. There is also a capacitive link in the converters structure, induction generator needs to absorb reactive power from the grid and passer power of converter is about 25 to 35 percent of full turbine power So, unlike the structure full turbines that used in wind turbine, in DFIG power electronic converters in terms of power it's not necessary to adequate with wind turbine.

During cause's network error, such as short circuit or voltage grid decrease, wind turbines can still be injected into the network. One of the problems caused by changes in voltage or symmetrical short circuit network in the DFIG, causes extra current in the rotor that can cause damage of rotor shunt winding and rotor side converter. That is why the common solution for wind generators in case of isolated disturbances the rotor-side converter and thus wind generator from the network, the network adapter in these circumstances will not be able to provide the required reactive power, in this case, if wind energy has a large share in power generation needed by the system, disconnecting the wind generator can have a negative impact on the stable network voltage.

In relation to wind energy during the smaller wind turbines disturbances until the system returns to its normal state get apart from the network. In conjunction with larger wind farms, often feels the need that remains in a state of disarray in connection with the network and continue to inject active power.

Today, reactive power compensation by using FACTS devices have been widely noted and investigated. The use of this equipment can be the perfect solution for inconsistency and immaturity of the network voltage in error conditions that as a result of using these compensators during the disturbance can be barrier of interrupting wind generators DFIG by required injection of reactive power. Static synchronous compensator (STATCOM) and static reactive power compensators (SVC) because of having fast dynamic could be appropriate options for supplying required power reactive.

The study's question: how get the improvement possibility's operation of wind farms based on DFIG in error condition without FACTS instrument?

This study theory consists of structure and capacity of converter-side in DFIG is designed so that during an error can enter the circuit as a STATCOM and take charge of needed reactive power generation.

2. STATCOM performance

FACTS devices are defined as alternating current power transmission systems which have controllers based on electronics power and other static controllers to enhance controllability and increase power transfer capability (Fazli et al., 2010).

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In wind energy applications fields, there are times that winds farms are exposed to short-term disturbances due to short-circuit errors. During these disturbances, the system voltage is quickly collapse (GE, 1997). Smaller scale winds turbines are usually cut from the system until return to normal operating conditions. For large wind farms, in most cases one of the basic requirements is that during the disturbances they need to stay connected to the system and also supports the system to return to their pre-disturbance (Okedu et al., 2011).

The parallel capacitor fixed bank or keying able as a traditional way of providing reactive power compensation for steady state utilization has been used. Of course they can't improve transient behavior and thus unable to fix the extra voltage problem. It should be noted that STATCOM is one of the most FACTS devices that capable of generating and / or absorbing reactive power and can be in any of the network sheens in order to support that sheen voltage (Kunte et al., 2012; Singh et al., 2009).

Equip STATCOM consists of a voltage source converter (VSC) and a DC energy storage that parallel is connected to the distribution network via a transformer coupling (Wang and Hsiung, 2011).

Voltage Source Converter Performance (VSC) is that tow head DC voltage storage change to a set of three-phase AC output voltage. This converter can steadily by changing the voltage range converter than sheen voltage, produce or absorbs reactive power. In this way, controlled flows occur between STATCOM and distribution network. When the system voltage is high, STATCOM is absorbing reactive power (Wang and Hsiung, 2011). Voltage source converter power uses power electronics equipment with forced commutation such as GTO, IGBT or IGCT. STATCOM main features include: fast response time, less space requirement, optimum voltage, high reliability and excellent dynamic characteristics under various operating conditions (Qiao et al., 2009a) Active and reactive power injection with STATCOM has been identified by following equations (Qiao et al., 2009a).

$$P = \frac{V1V2SIN\delta}{X}$$

$$Q = \frac{V_1(V_1 - V_2\cos\delta)}{X}$$

In recent relations δ, is the difference angle between V_1 and V_2 In steady state operation, V_2voltage produced byV_1voltage source converter same phase.

$\delta = 0$ So the only reactive power will flow $P = 0$ Therefore, the equation can be rewritten as follows:

$$Q = \frac{V_1(V_1 - V_2)}{X}$$

Above equation result in generated or absorbed reactive power by a STATCOM (Qiao et al., 2009b)

3. STATCOM substituting method at the time of error

One of the problems caused by changes in voltage or short symmetrical network connection in DFIG, excess extra current in the rotor, which can cause damage in rotor coil and rotor side converter .because of these the common solution for wind generators in case of turbulence is separating the converters side- rotor and therefore wind generator from the network, in these condition converters side- network will not be able to provide the required reactive power, in this case, if wind energy have a large share in generating required power systems, separating wind generators can have a negative impact on the stability and fixing network voltage.

Today, reactive power compensation by using FACTS devices have been widely noted and investigated. Using this equipment can be a good solution for instability and unfixing network voltage in error condition that in result of these compensators during distributing can be barrier of interrupting DFIG wind generators by injecting required reactive power. Static synchronous compensator (STATCOM) and reactive power compensator (SVC) due to having a fast dynamic can be appropriate required options for supplying reactive power. Using STATCOM raise costs, to reduce costs here as a proposed method existing structure and capacity side converter in DFIG can be designed so that during occurring error as a STATCOM enter a circuit and taking the charge of producing the required reactive power, in this case avoid of using two transducers separately and by designing a convertor of suitable capacity can have two usage. If the rotor side converter (RSC) has sufficient capacity, in terms of errors no need to get out and this converter can stay in orbit without suffering damage. Thus back to back DFIG converters can help to keep voltage by supplying reactive power and also prevent the Tripp DFIG. In addition, it would also bring substantial economic benefits, because there will be no need for the use of FACTS devices such as STATCOM. In this case, DFIG works about Voltage Regulation function. DFIG converters power is more and therefore does not block RSC converter. During error can use DFIG converters for reactive power compensation instead of STATCOM. Thus the costs become less.

4. Test system

Fig. 1 shows the used test diagram system to study in MATLAB and SIMULINK software environment. Test model include a power network 120 kV and 60 Hz which feeds a 25 kV distribution system through a dimming transformer 25-120 kV and 47MVA. This distributed system then through a transformer 0.575-25 kV and 12 MVA is connected to a 575Vsystem.

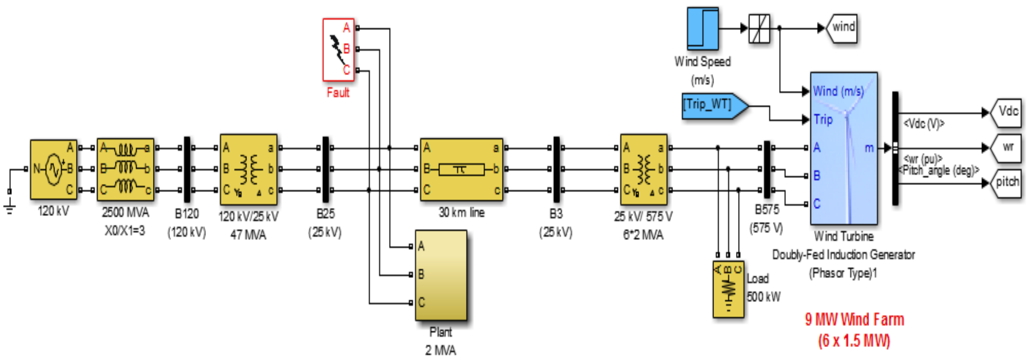

Fig. 1. Studied network in MATLAB SIMULINK software.

Two consumable loads exist in the system: once MVA 2 with a power factor 0. 9. Lag is about 30 km from transmission line and a static load in V 575. In sheen 500 kV .30 km long transmission line with 25 kV voltages is displayed by *Π*model .A wind farm

DFIG-based consists of six wind turbines connected to 575 V sheen. Capacity of each wind turbines was 1. 5MW and in total 9 MW .The network side converters in DFIG link voltage DC hold almost in constant amount of 1200 V during normal operational conditions. In this study, wind farm with a capacity of 9 MW by using of toolbox Sims Power System in MATLAB.SIMULINK software is displayed. Six wind turbines based on DFIG as a DFIG equation has been showed. Each of wind turbines DFIG is one of wind turbine generator 1.5 MW. Simulation analysis was performed by using SPSS MATLAB.SIMULINK software.

5. The output of the system in single-phase error condition to ground without STATCOM and with a strong RSC converter

If the rotor side converter (RSC) has sufficient capacity, in terms of errors no need to get out there and this converter can stay in orbit without suffering damage. Thus converters back to back DFIG can help to maintain the voltage by supplying reactive power and also prevent the Tripp DFIG. In addition, it would also bring substantial economic benefits, because there will be no need for the use of FACTS devices such as STATCOM. In this case, DFIG works in about Voltage Regulation function. DFIG converters power is more and therefore RSC converters does not block. During error can use DFIG converters instead of STATCOM for compensation reactive power. So the costs would be decreased. Fig. 2 shows the amount of voltage in this mode. The voltage is 0.8 at error time, and is 1at the rest of the time. Fig. 3 shows the flow of wind turbines in this mood.

As it is clear in Fig. 3 without STATCOM mode and with strong RSC converter observed .at the time of error 5 seconds circuit slowly increases and reached to 0.6 and at different time is about 0.2 and also due to extra reactive power generation doesn't have considerable current. On Fig. 4 see the reactive power amount. As it has been shown in the Fig. 4, the producing reactive power at 5 Sec errors moment reached to 6 because of using strong convertor RSC reached to this amount. (At other times its zero). In the Fig. 5 the amount of dc-link voltage can be observed.

As its observable in the dc link voltage figure of back to back voltage converters the amount of 5 sec error moment reached between 1140 to 1250and in the rest of the time is 1200 normal. As expected required reactive power to overcome the error by DFIG converters were produced. This is observable in DFIG process production.

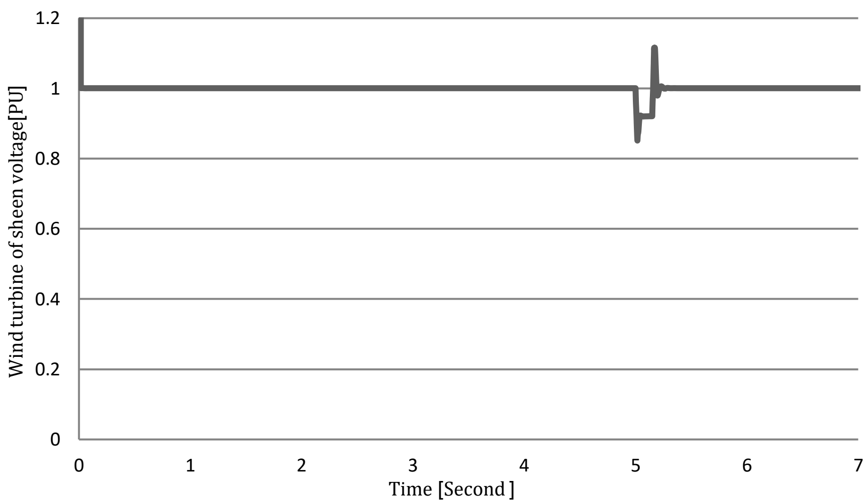

Fig. 2. Wind turbine of sheen voltage in no –STSTCOM with strong reactive RSC.

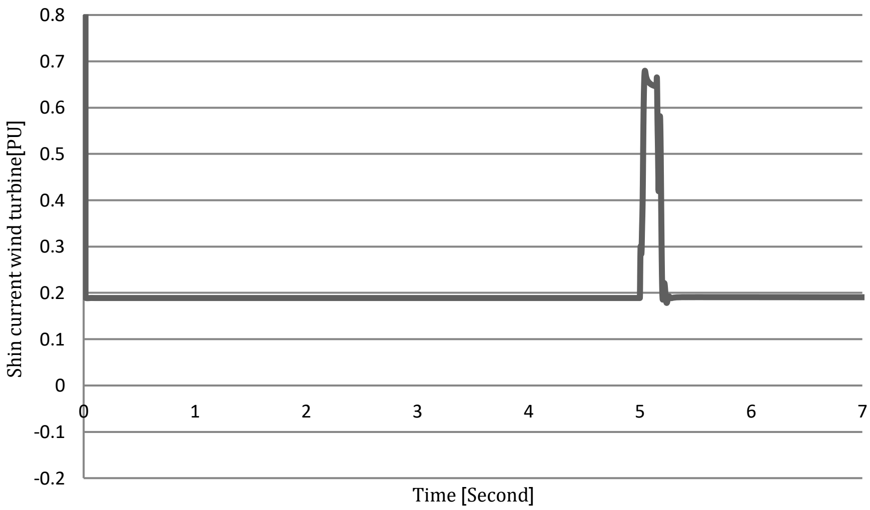

Fig. 3. Shin current wind turbine in non-STATCOM mood and a strong RSC converters.

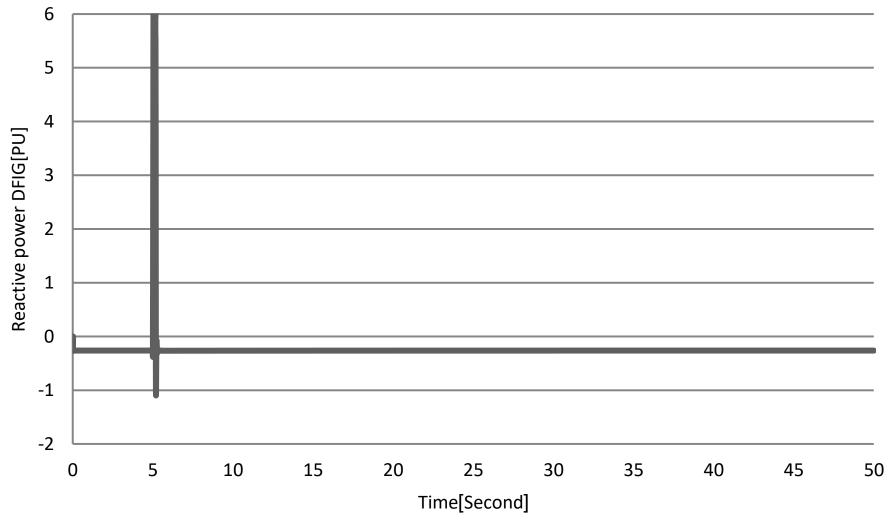

Fig. 4. Reactive power DFIG In the non-STATCOM mood and with strong RSC converters.

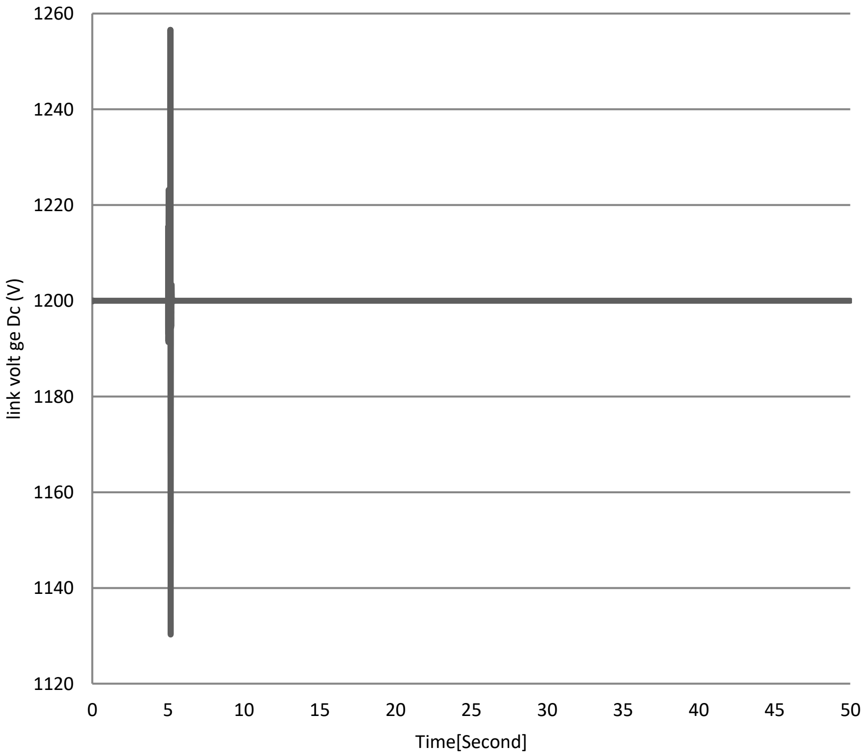

Fig. 5. Link voltage Dc back to back converters voltage at no- STATCOM mood and with strong RSC converter.

6. Conclusion

Integration of large wind farms in power systems creates numerous challenges in the field of operation and system security. One of these challenges in the field of system security is consist of vulnerability versus exiting of common mode caused by short circuit errors. During disturbances in system such as short-connection errors, the lightning on transmission lines and, etc., wind generators may have to be disconnected from the power network. Exiting these generators from the grid has negative impact on system stability, especially if the penetration of wind power in the network has reached to very high level.

Consider a mood of network error on DFIG-based wind farm which is imposed. In this case, the blocked rotor side converter (RSC) related on DFIG is a known guideline in terms of protecting RSC against extra current. Because of having small capacity, grid side converter (GSC) can't provide sufficient reactive power and voltage support, so there will be a risk of voltage instability. Therefore, power companies usually disconnecting wind turbines from the network immediately to prevent such circumstances. When normal operation conditions Backed, the generator can be connected again. With the rapidly increasing wind power penetration in power systems, leaving a large number of large wind turbines in a big wind farm over a network error conditions may affect the voltage stability of the power system. Compensation of dynamic reactive power by using of FACTS devices as a major solution to the problem of voltage instability and achieving sustainable exploitation of DFIG-based wind farm during error conditions is widely studied by researchers. Static synchronous compensator (STATCOM) and a compensator static reactive power (SVC) are two accepted options to provide dynamic reactive and controlled power because they have fast response speed. as proposed, designing back to back converters in DFIG was in such a way that these converters are capable of providing reactive power and voltage support in the network error condition without existing of FACTS devices. This idea is potentially reduced the costs.

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