Abstract— Spread of wind power plants connected to the grid has raised some concerns about the weakness of disturbances resulting voltage drop. Doubly fed induction generators are very sensitive to sudden changes of stator voltage. Fault conditions, a sudden sharp rise in the rotor will link voltage DC converters. Increase the voltage and current, causing severe damage to the converters. This paper presents two methods for reducing the voltage and current standard. Accuracy of the method is verified by simulation results PSCAD / EMTDC for a 1.3 [mw] wind turbine manufactured by Siemens Company.

Keywords— Wind Turbine, Doubly Fed Induction Generator, Islanding, Low-Voltage Ride-Through, protection System

I. INTRODUCTION

With rising fuel prices and serious environmental issues, trends, increased use of renewable energy sources and usage of these resources extend from year to year. So much so that by 2020, the number is 20 percent of the electrical energy produced through wind resource to provide[1]. The history goes back many centuries of wind energy. In Iran, Khorasan provinces where there are two thousand year old relics of windmills. However, will not it pass more than three decades of power generation with wind energy. During this short period of time has done extensive research in the fields of wind power plants. Is growing significantly adding renewable energy to the power grid. In the coming years is to generate electrical energy the best choice among several options, wind energy. However, increasing the power grid wind power plants to increase their influence in the whole system. So, for example, seems necessary to investigate the stability of wind farms connected to the network and control capabilities. Due to the low price, strength and require less maintenance, are increasing the use of induction generators in wind energy conversion systems. Compared with conventional induction generator, doubly fed induction generator is superior because of the following advantages[2]:

a) Below and above synchronous speed synchronous dynamic performance capability ranges.

b) Active power generation capacity at constant frequency.

c) Separate control of active and reactive power.

d) Lower nominal power converters used.

e) The ability to control reactive power, resulting in voltage control.

At present, most of the double fed induction generator (DFIG) wind power plants use[3]. DFIG is a winding rotor induction generators, in which the stator and rotor directly through back-to-back converter is connected to the network[4]. Is composed of two voltage converters back to back, one of which is connected to the rotor (RSC), the other is connected to the network (GSC). The network adapter will work with the network frequency. The control objective is to connect the converter to maintain a constant link voltage DC. This control is accomplished through the components of d and q. But the changing frequency of rotor side converter turbine speed. The objective is to control the rotor side converter, the electric motor and the rotor excitation current. Rotor excitation current is controlled with the d –component.

II. EQUATIONS OF WIND TURBINE

DFIG makes possible three-phase current is injected into the rotor wiring. This is achieved with a set of slip rings. Unlike the squirrel cage induction machine where the rotor with the stator rotating magnetic field is produced dfig another option to create the desired rotor current provides independent. This additional degree of freedom can be used to control the active and reactive powers in a wide range of Speed. Wind turbine equation is as follows:
ISSN (Online): 2305-0225  
Issue 7, January 2014, pp. 322-328

\[ PM = \frac{1}{2} \rho_{air} V^3 \pi R^2 C_p(\lambda, \beta) \]  \hspace{1cm} (1)

\[ PM = \omega_M T_m \]  \hspace{1cm} (2)

\[ C_p = \frac{P_M}{P_{air}} \]  \hspace{1cm} (3)

\[ \lambda = \frac{\omega_M R}{V} \]  \hspace{1cm} (4)

\( P_M \) is Turbine mechanical power, \( \rho_{air} \) wind density, \( V \) wind speed, \( \omega_M \) turbine rotation speed, \( \beta \) angle of wind turbine blades, \( T_m \) mechanical torque, \( R \) radial turbine, \( C_p \) Power coefficient curve, for a given peak velocity \( V_{Rm} \omega_l = \) as well as the characteristics are given by the manufacturer.

It is noteworthy that the coefficient should not exceed the theoretical limit of \( C_{p, MAX} = \frac{16}{27} = 0.59 \) that this amount is called the Betz limit.

### III. WORKINGS OF DFIG

Mechanical power into electrical power to the machine shaft in the double-fed induction generator, which uses the stator and rotor windings will produce electricity AC for the national grid. Moreover, the machine acts as a synchronous generator with synchronous speed (ie the speed of the generator shaft to be rotated for power generation in the electric AC network frequency) that can be set to power-frequency current to the rotor windings. The three-phase synchronous generator, when an external mechanical force (such as a main driver) causes rotation of the rotor generator, Static magnetic field which is fed current winding rotor, generator rotor rotates at the same speed.

\[ F_{stator} = N_{roter} \times N_{poles} \times \frac{1}{120} \]  \hspace{1cm} (5)

\( F_{stator} \), frequency of the voltages induced AC in the stator windings double-fed induction generator.

\( N_{roter} \), speed double-fed induction generator.

\( N_{poles} \), the number of double-fed induction generator poles per phase.

Using Equation (5), it is possible to determine when the rotor speed of generator (\( N_{roter} \)) is equal to the synchronous speed of the generator (\( N_s \)). Frequency AC voltages induced in the stator windings of the generator (\( F_{stator} \)) is equal to the frequency of the ac power grid (\( F_{network} \)). This means that the Damned, Rotating magnetic field rotates through the generator stator windings, not only due to the rotation of the rotor of the generator, but due to the spin injection current into AC generator rotor windings. So in a DFIG, both the frequency of the rotation speed of the rotor and the rotor windings are effective to determine the rotation rate of the magnetic field passing through the stator windings of an alternating voltage induced in the stator coils are fed with the frequency AC current. With regard to the practice of double-fed induction generator, so when the magnetic field in the rotor in the same direction as the rotor rotates the generator rotor speed and rotor speed, the magnetic field is proportional to the added Frotor. Conversely, when the magnetic field in the rotor rotates in the opposite direction generator rotor, rotor speed and rotor speed, the rotor magnetic field, are low among, Fig.(1). Thus, the double fed induction generator to this point, the voltage applied to the stator, the rotor voltage is applied to the grid by power converters. Allow operation in a wide speed range allows the system. Converter compensates the difference between mechanical and electrical speed by flow injection with variable frequency[5].

### IV. DYNAMIC MODEL OF DFIG

Dynamic model of DFIG in the synchronous reference frame and a two phase \( d-q \) is expressed by the following equations[6]:

\[ V_d = R_i + L_i \frac{di_d}{dt} + L_n \frac{di_q}{dt} - \omega l (L_n \frac{di_d}{dt} + L_i \frac{di_q}{dt}) \]  \hspace{1cm} (6)

\[ V_q = R_i + L_i \frac{di_q}{dt} + L_n \frac{di_d}{dt} + \omega l (L_n \frac{di_d}{dt} + L_i \frac{di_q}{dt}) \]  \hspace{1cm} (7)

\[ V_d = R_i + L_i \frac{di_d}{dt} + L_n \frac{di_q}{dt} - (\omega_q - \omega_l) (L_n \frac{di_d}{dt} + L_i \frac{di_q}{dt}) \]  \hspace{1cm} (8)

\[ V_q = R_i + L_i \frac{di_q}{dt} + L_n \frac{di_d}{dt} + (\omega_q - \omega_l) (L_n \frac{di_d}{dt} + L_i \frac{di_q}{dt}) \]  \hspace{1cm} (9)

Active and reactive power transfer through the rotor and the stator are calculated from the following equations:

\[ p_r = V_d i_d + V_q i_q \]  \hspace{1cm} (10)

\[ p_s = V_d i_d + V_q i_q \]  \hspace{1cm} (11)

\[ Q_s = V_q i_d - V_d i_q \]  \hspace{1cm} (12)
For a complete transfer of power from the rotor system, we have the relations (15) and (16):

\[ p_{dc} = 0 \Rightarrow p_s = p_r \]

And there are also the following relation between the rotor and stator electrical power:

\[ p_r = s p_s \]  

(17)

Here s is the slip.

And the electromechanical torque is obtained from the following equation:

\[ T_{em} = \lambda_{d} i_{d} - \lambda_{q} i_{q} \]  

(18)

Showing an equivalent circuit of d and q reference generator synchronous machine following figures, Fig.(2).

V. LVRT CAPABILITY OF DFIG

LVRT capability of DFIG is connected to a generator to the grid with dynamic stability, and support network voltage disturbances in the transmission system by generating sufficient reactive power[7]. Network error, even far away from the location of wind turbines can cause a voltage drop at the connection points DFIG. As a result, low voltage, an imbalance between power input and power output of the turbine generator, the car accelerated , producing stator and rotor currents increase. High current generator rotor, automatically increases the current through the rotor and cause damage. Another effect of the voltage drop on the grid side converter increases the voltage of the DC link. Conventionally, it is plausible that in the event of a fault or disturbance such as voltage drop on the grid, DFIG are disconnected from the network. With greater penetration of wind power, to change the standard. For a stable and reliable power generation, wind farms must be connected to the grid during transient disturbances, and produce reactive power to the system recovery voltage. New techniques are presented in this paper, to enhance the LVRT capability of DFIG. The minimum time for standard low voltage[8] have been described, Fig.(3).

VI. PROPOSED METHODS

May be in response to a network error, an offset voltage is detected, an error that it can take more time and increases the stator currents of more than nominal value, resulting in an increase in the rotor currents, and is damaged Converters[9]. The increase in currents will also cause a significant increase in the DC link voltage. Both the event, increasing the voltage and current will cause serious damage to electronic converters, the need to protect these converters. In the past, when the fault happens, simply to protect it from the grid...
were separated, but with the expansion of wind power plants increased their share of such production, which keep them in the network, will When the inevitable errors. It is essential to have proved safe, fast and accurate detection of low voltage. To achieve quick response and high precision in the wind power system is used of the detection of the rotor currents to track the symmetrical three-phase voltage. In the first method, the rate of the rotor currents is good is turned on the rotor side converter. If the currents rate exceeds the maximum allowed rotor, will cause the converter transformer is turned off and the rotor windings are shorted. In this method, the rotor currents can be used to start a protective circuit, Fig.(4).

The second method, under fault conditions is reduced by the use of resistance, increasing the DC link voltage. As shown in Fig.(7). Resistance using a breaker is connected to the DC link. Breaker is switched on when the DC link voltage is greater than the threshold value. Resistor is connected to the DC link. Consumed can be stored on the resistance in the DC link. When the error was resolved, separates breaker resistance from the link DC ( Fig. 6 and 7 ).

VII. Simulation

Confirmed the validity of the proposed method by PSCAD/EMTDC simulation results, for a wind turbine 1.3MW Siemens Company.
Fig. 9 - Voltage reduction for duration of 150 msec

Fig. 10 - Three-Phase Voltage Power Networks

Fig. 11 - The mechanical speed of the rotor

Fig. 12 - DC link voltage without using the proposed methods

Fig. 13 - DC link voltage using the first method proposed

Fig. 14 - DC link voltage, the concomitant use of first and second method proposed
In Fig.(9) the voltage decreases to zero per unit for the duration of 150 msec and, respectively, in the form of line voltage and rotor mechanical speed (10) and (11) are shown. As you can see, this circuit has been tested in three modes:

a) First case: no use of the proposed methods (Fig.12 and 15).

b) Second case: the first method proposed (Fig. 13 and 16).

c) Third case: use of first and second proposed method (Fig. 14 and 17).

VIII. CONCLUSION

We conclude that in the first case, we increase the voltage, the circuit also is unstable.But not in the second mode unstable orbit, but the problem continues to cause severe damage to the converter voltage is increased. In the third case, the circuit is suitable answer the LVRT in Standard Time zero per unit for the duration of 150 msec (Fig. 3).

Appendix

DFIG parameters are given in Table (1).

<table>
<thead>
<tr>
<th>MODEL</th>
<th>SWT 1.3-62 Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pn</td>
<td>1.3(MW)</td>
</tr>
<tr>
<td>Vn</td>
<td>690(V)</td>
</tr>
<tr>
<td>Rs</td>
<td>0.00536(PU)</td>
</tr>
<tr>
<td>Ls</td>
<td>0.13957(PU)</td>
</tr>
<tr>
<td>Rr</td>
<td>0.00536(PU)</td>
</tr>
<tr>
<td>Lr</td>
<td>0.13957(PU)</td>
</tr>
<tr>
<td>Lm</td>
<td>4.2848(PU)</td>
</tr>
</tbody>
</table>

Table. 1 - Parameter values for wind turbine DFIG 1.3MW manufactured by Siemens (SWT 1.3-62).

References


[8] Hua Geng, Cong Liu, Geng Yang, "LVRT Capability Of DFIG-Based WECS Under Asymmetrical Grid Fault Condition", IEEE