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Modeling of Doubly Fed Induction Generator with Low Voltage Ride through Mechanism

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ABSTRACT: With the rapid development of wind power industry in our country, more and larger scale wind farms are connected to the electricity grid, which makes the grid safety more significant problem, so the study of wind generator and the low voltage ride through (LVRT) technology is very significant. Here we are going to deal with low-voltage ride-through (LVRT) capability of wind turbines (WTs) and in particular those driven by a doubly-fed induction generator (DFIG). Most countries require that Wind Turbines should remain connected to the grid to maintain the reliability during and after a short-term fault, it is required for Wind Turbines to contribute to system stability during and after fault clearance. To fulfill the LVRT requirement for DFIG-based WTs, a converter is used between the grid and generator which boost the voltage to the required level or limits the voltage when it exceeds. Further, it is required to limit the DFIG transient response oscillations during the voltage sag to increase the gear lifetime and generator reliability. This paper provides the modeling of doubly fed induction generator and the low voltage ride through capability of the DFIG.

KEYWORDS:-DFIG,LVRT, reliability, short term fault, transient.

I. INTRODUCTION

1. PROCESS OVERVIEW**:**

Efforts are geared towards gird integration of renewable energy sources into a grid as a result of environmental concerns and the quest for energy security. Among the renewable energy sources, wind energy stands out because of its technological maturity, good infrastructure and relative cost competitiveness.

2. EXISTING SYSTEM:

At present, the wind power growth rate stands at 20% annually and it is predicted that 12% of the worlds may come electricity from wind power by the year 2020. However, grid integration of the Wind

Energy Conversion System (WECS) can potentially affect the power system negatively due to fluctuation in wind power. The WCES exhibits variability in its output power because of the stochastic nature of wind resource as a result of incessant changes in weather conditions. This intermittent and diffuse nature of the wind power introduces a new factor of uncertainty on the grid and may have a negative impact on the grid integrity i.e. the power quality, the system security and the system stability. The dynamics and the control of conventional generators in a power system vis-a-vis grid interaction are well understood and falls under the control capability of the utility operators.Wind energy is controlled by nature and this can have a repercussive effect on the power system. For wind generators to effectively replace the normal conventional generators, then, it must be able to provide the same ancillary voltages, ensuring load following, maintaining grid frequency, and contributing to fault current. Wind the penetration level is increased, the technical impact on the grid integrity may arise which needs to be well understood.

3. PROPOSED SYSTEM:

Therefore, implies the need for certain technologies to enable smooth and proper integration of WECS to the grid. As such the necessary specifications for such technologies need to be properly understood and quantified. This papers sets out to address this. It discusses the various challenges of WECSs when directly integrated into the grid, to reduce

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the faults and low voltage ride through a converter is used between the grid and generator side for smooth integration through different mitigating strategies using MATLAB software.

II. LITERATURE REVIEW

Modeling and control of a wind turbine drive DFIG during grid voltage dip based on DIGISILENT/Power Factor Zaiping panetal, The low voltage ride through (LVRT) capability of DFIG has caused more concern. And for testing requirements of LVRT for DFIG WT, this paper propose control strategies for LVRT of DFIG WTs by injecting reactive power into grid. Reactive power allocation are decided by voltage sag levels. When grid voltage drop to 30%, grid-side converter (GSC) works as a STATCOM. Their maximum limited reactive current expressions are also considered. An active power control strategy is proposed considering the recovery rate requirement of the active power. Furthermore, a novel RMS model is presented based on external characteristics. Simulations on a 2.5MW DFIG wind turbine demonstrate that the output characteristics satisfy requirement of grid code of wind power.

Study on Modeling Simulation and Identification of Wind Generator Based on DIGISILENT Chao Sheng,et al
The integration of large scale wind farms bring serious influence to the stability of power system. In this paper, a model of doubly-fed induction generator based wind turbine with capacity of 1.5 MW is constructed using the module of parameter identification in simulation software DIGISILENT. Then, to decrease the modeling error came from the difference between the wind energy utilization factor table in the Dig SILENT model and that of the actual wind generator, a new modified wind energy utilization factor table is developed. Finally, the DFIG-based wind turbine model, with corresponding identified parameters, is used to the practical wind generator by its actual operation data. The simulation result show that the active power output by the constructed simulation model has the similar tendency with the practical wind power data, i.e. the proposed method and the constructed model are effective.

Modeling and Fault Analysis of Doubly Fed WindPower Generation SystemsLiang Dong,School of Electrical Engineering Shandong University Jinan, China.
Combining current reference PWM (CRPWM) and sinusoidal PWM (SPWM), with the aid of stator-flux-oriented and grid-voltage-oriented vector control strategy, the doubly fed wind power generation system is modeled based on the mathematical model. According to Chinese recent regulations on low voltage ride through (LVRT), this paper proposed a novel LVRT voltage control strategy which can provide reactive power in grid voltage recovery. From the voltage and flux equations of the doubly fed induction generator (DFIG), this paper analyzed transient characteristics of the stator and rotor flux when symmetrical short-circuit fault occurred close to the DFIG, and derived expressions for the short-circuit current. The impact of crowbar protection and grid side converter (GSC) is analyzed. Finally, a simulation model is established in PSCAD/EMTDC. Simulation results verify the correctness of new control strategy and expressions proposed by this paper.
DFIG Wind Turbine Modeling and Validation for LVRT Behavior
Jing He, Qing Li, et al
As the increasing of installed capability of wind power in power system, the dynamic wind turbine models are required for wind turbine and wind farm stability assessment. For this reason, the wind turbine models have to be simulated accurately compare to the wind turbine operation behavior especially during grid fault. An accurate DFIG wind turbine dynamic model is presented. For low voltage ride through (LVRT) simulation, the 5th and 3th order generator model, including converter with crowbar and chopper, pitch angle controller, drive train model are analyzed. Simulations are carried out to analyze the model structure and parameters influence to LVRT behavior. The models are simulated, and validated with the wind turbine LVRT field-test data. Validation results show the accuracy of the model.

Phase Angle Compensation Control Strategy for Low Voltage Ride Through of Doubly-Fed Induction Generator
W. Wang, *Senior Member, IEEE*
Crowbar-based control is one of the main low voltage ride through (LVRT) control methods for doubly-fed induction generator (DFIG), but converter is still at risk of being damaged by over-current at rotor side after crowbar exits during fault recovering period. For the issue, a model for fault process analysis based on equivalent dynamic model of DFIG is established. The mechanism of phase angle jumping when fault occurring and grid voltage

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recovering and its impact on vector orientating precision are analyzed. Based on this, jumping phase angle compensation principle is proposed to improve existing LVRT control strategy. Then the process of control is divided into four periods, i.e., normal operation period, crowbar switching period, crowbar exiting period and grid voltage recovering period. In normal operation and crowbar exiting period, stator flux orientation control of DFIG is applied. In crowbar switching period, IGBT pulses of rotor side converter are locked, but grid side converter maintains normal operation. In grid voltage recovering period, phase angle compensation control is applied. Simulation results show that over-current in grid voltage recovering period can be effectively limited by the proposed control strategy.
Low-Voltage Ride-Through Capability Enhancement of DFIG-Based Wind Turbine With a Resistive-Type SFCL Connected in Series With Rotor Winding
Yi Zhang State Grid Fujian Electric Power research Institute State Grid Corporation of China Fuzhou 350007, China
To satisfy with the low-voltage ride-through (LVRT) requirements from both the grid side and doubly-fed induction generator (DFIG) based wind turbine (WT) itself simultaneously, this paper presents a novel LVRT scheme by using a resistive type superconducting fault current limiter (SFCL) connected in series with the DFIG rotor winding. The peak fault rotor current characteristics are obtained and further utilized to optimize the SFCL resistance. With the optimized SFCL resistance and operational conditions from the DFIG, system design and circuit modeling of the SFCL are further discussed. Simulation results obtained show that the proposed SFCL-based LVRT scheme is favored to limit the rotor inrush currents and to protect the RSC and gearbox whenever the grid fault occurs. The terminal for the efficient connection to the grid.voltage of the DFIG is also improved with a certain amount of reactive power supplied.

III. DOUBLY FED INDUCTION

GENERATORS

Doubly-fed electric machines are electric motors or electric generators where both the field magnet windings and armature windings are separately connected to equipment outside the machine. By feeding adjustable frequency AC power to the field windings, the magnetic field can be made to rotate, allowing variation in motor or generator speed. This is useful, for instance, for generators used in wind turbines.Doubly fed electrical generators are similar to AC electrical generators, but have additional features which allow them to run at speeds slightly above or below their natural synchronous speed. This is useful for large variable speed wind turbines, because wind speed can change suddenly. When a gust of wind hits a wind turbine, the blades try to speed up, but a synchronous generator is locked to the speed of the power grid and cannot speed up. So large forces are developed in the hub, gearbox, and generator as the power grid pushes back. This causes wear and damage to the mechanism. If the turbine is allowed to speed up immediately when hit by a wind gust, the stresses are lower and the power from the wind gust is converted to useful electricity.One approach to allowing wind turbine speed to vary is to accept whatever frequency the generator produces, convert it to DC, and then convert it to AC at the desired output frequency using an inverter. This is common for small house and farm wind turbines. But the inverters required for megawatt-scale wind turbines are large and expensive. Doubly fed generators are one solution to this problem. Instead of the usual field winding fed with DC, and an armature winding where the generated electricity comes out, there are two three-phase windings, one stationary and one rotating, both separately connected to equipment outside the generator. Thus the term "doubly fed".

One winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency. The other winding (traditionally called the field, but here both windings can be outputs) is connected to 3-phase AC power at variable frequency. This input power is adjusted in frequency and phase to compensate for changes in speed of the turbine.

Adjusting the frequency and phase requires an AC to DC to AC converter. This is usually constructed from very large IGBT semiconductors. The converter is bidirectional, and can pass power in either direction. Power can flow from this winding as well as from the output winding.

Double Fed Induction Generator, a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly (see brushless doubly-fed electric machines), but there are problems with efficiency, cost and size. A better alternative is a brushless wound-rotor doubly-fed electric machine. The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ

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from the grid frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed. The control principle used is either the two-axis current vector control or direct torque control (DTC). DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator.

The doubly-fed generator rotors are typically wound with 2 to 3 times the number of turns of the stator. This means that the rotor voltages will be higher and currents respectively lower. Thus in the typical ± 30% operational speed range around the synchronous speed, the rated current of the converter is accordingly lower which leads to a lower cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher than rated rotor voltage. Further, the voltage transients due to the grid disturbances (three- and two-phase voltage dips, especially) will also be magnified. In order to prevent high rotor voltages - and high currents resulting from these voltages - from destroying the IGBTs and diodes of the converter, a protection circuit (called crowbar) is used.

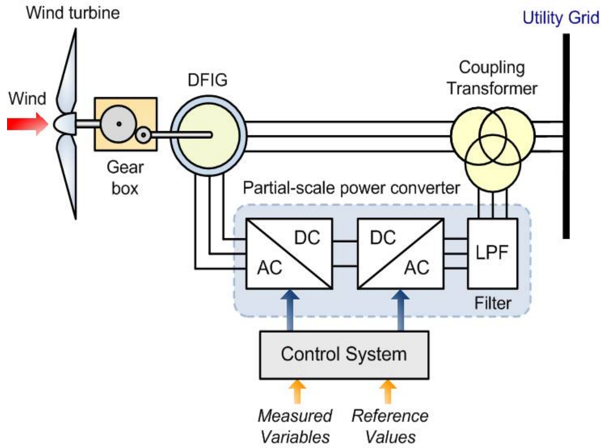

fig.2.1 doubly fed induction generator connected to a wind turbine

Fig.2.1 shows the diagrammatic representation of doubly fed induction generators As a summary, a doubly-fed induction machine is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in wind power applications. First, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances (low voltage ride through, LVRT). Second, the control of the rotor voltages and currents enables the induction machine to remain synchronized with the grid while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions. Third, the cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25-30%, is fed to the grid through the converter, the rest being fed to grid directly from the stator. The efficiency of the DFIG is very good for the same reason.

IV. CONVERTERS

1. DC TO DC CONVERTER:

There are various types of power electronic converters which are frequently used in electric power system applications such as power converter, regulated power supply, DC power supply and so on. The power electronics converters can be classified as AC to DC converter or Rectifier, DC to AC converter or Inverter, AC to AC converter, DC to DC converter, and so on. These converters are again classified into different types based on different criteria. If we consider DC to DC converters, these are classified as DC to DC buck converter, DC to DC boost converter, and DC to DC buck-boost converter. Here, we discuss in detail about the DC to DC converters, operating principle and functionality.

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A DC-DC converter is a power electronics device that accepts a DC input voltage and also provides a DC output voltage. The output voltage of DC to DC converter can be greater than the input voltage or vice versa. The converter output voltages are used to match the power supply required to the loads. The connection and disconnection of power supply to the load can be controlled using a switch in the simple DC to DC converter circuit. DC to DC converter circuits consists of a transistor or diode switch, energy storage devices like inductors or capacitors and these converters are generally used as linear voltage regulators or switched mode voltage regulators. DC to DC converters are used to provide DC regulated power supply, constant DC power supply to the electrical and electronics project circuits.

2. DC TO DC BOOST CONVERTER:

The low input DC voltage is converted into high output DC voltage using DC to DC boost converter. As the input voltage is stepped up compared to output voltage, hence, it is also called as a step up converter. Generally, DC to DC converters can be designed using power semiconductor switching devices and components. The Buck Boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

The continuous conduction mode circuit of the DC to DC boost converter is shown in the figure that consists of an inductor, capacitor, switching device, diode, and input voltage source. This boost converter circuit switch is controlled using a pulse width modulator (PWM). If this switch is in ON state, then energy will be developed in the inductor and thus more energy will be delivered to the output.

The discontinuous conduction mode circuit of the DC to DC boost converter is shown in the figure that consists of elements such as capacitor, inductor, voltage source, diode, and switching device. In this discontinuous conduction mode, if the switch is in ON state, then energy will be delivered to the power storage element, inductor. If the switch is in OFF state for some period, then the inductor current will reach zero until the next switching cycle is on. Thus, the capacitor gets charged and discharged with respect to the input voltage. But, here the output voltage in discontinuous conduction mode is less than the output voltage in continuous conduction mode.

Similarly, buck converters are used for converting high input DC voltage into low output DC voltage. Buck-boost converters are used for maintaining output DC voltage high or low based on the input DC voltage source. If the input DC voltage is high, then the output will be low and vice-versa. Thus, we can maintain regulated DC voltage using buck-boost converters.

3. BUCK BOOST CONVERTER:

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch. It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

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In step up mode $V_{in} < V_{out}$ in a Buck Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck Boost converter in stepupmode.

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

In step down mode $V_{in} > V_{out}$ in a Buck Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck boost converter in step down mode.

$$V_{in} > V_{out} \text{ and } I_{in} < I_{out}$$

V. LOW VOLTAGE RIDE THROUGH

LVRT (Low Voltage Ride Through – also known as FRT - Fault Ride Through) has become a crucial feature of the wind turbine control system. The LVRT-term is capturing the ability of a wind turbine (or in reality a wind park) to stay connected to the grid throughout a short mains voltage drop (a brownout) or a mains failure (a blackout).

When the voltage of the grid is dropping it is essential that a wind park stay online in order to prevent major blackouts. It is not only essential that the park stays online - it is equally essential that the park is working actively to compensate for the faulty grid condition. In China major blackouts (as a result of entire wind parks tripping and getting offline as a result of a brownout) have been seen. This has increased the focus of the LVRT feature of the wind turbine control system.

For short system faults (lasting up to 140ms) the wind farm has to remain connected to the grid. For supergrid (HV-grids) voltage dips of longer durations the wind farm has to remain connected to the grid up to more than 3 minutes. During grid faults or brownouts a wind farm has to supply maximum reactive current to the grid without exceeding the transient rating of the plan..On super-grids during voltage dips lasting more than 140ms the active power output of a wind farm has to be retained at least in proportion to the retained balanced super grid voltage

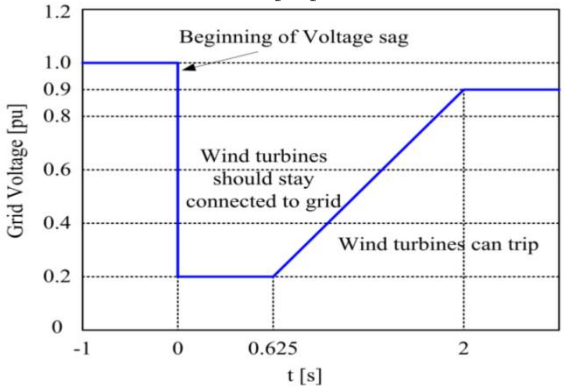

Fig5.1 low voltage ride through

As mentioned the LVRT-demands are individually specified by the grid operators and might therefore vary from operator to operator and from country to country. For wind turbines the LVRT testing is described in the standard IEC 61400-21.The LVRT-feature of wind turbine controls from DEIF WPT in combination with our Park Power Management solutions (including our forecasting solution) is all a wind park owner need to be in perfect compliance with the demands of grid operators worldwide.

VI. CONCLUSION

Thus the doubly fed induction generator is modeled and simulated in MATLAB software. The low voltage ride through of DFIG is modeled and a converter is used in between the grid and generator to boost the voltage when LVRT occurs.

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DFIG is a variable speed generator and therefore has the variable speed advantages compared to fixed speed generators. It more fully converts the available wind power over a wider range of wind speeds with less mechanical complexity but more electrical and electronic complexity. A disadvantage of the DFIG compared to the permanent magnet synchronous generator is that the DFIG requires a speed increasing gearbox between the wind turbine and the generator whereas the PMSG can be constructed with a sufficient number of poles to allow direct drive. The Buck Boost converters are used in self-regulating power supplies, here the converter used as a protection device when low voltage occurs.

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