OVERVIEW LVRT CAPABILITY OF DFIG TECHNIQUES

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ABSTRACT

Low Voltage Ride Through is an important feature for wind turbine systems to meet the conditions and requirements of the grid code. In case of wind turbine technologies using doubly fed induction generators the reaction to grid voltage disturbances is very sensitive which considers as a major drawbacks of using the Doubly Fed Induction Generators (DFIG). Protection techniques which include hardware or software must be implemented to protect the converter from tripping and provide uninterruptible operation to the DFIG during severe grid voltage faults. Methods for Ride Through operation of such system are presented.

Keywords: doubly fed induction generator (DFIG); low voltage ride through (LVRT); grid defaults.

I-INTRODUCTION

Wind energy generation has been noted as the most rapidly growing renewable energy technology. The increasing penetration level of wind energy can have a significant impact on the grid, especially under abnormal grid voltage conditions. Thus, the power grid connection codes in most countries require that wind turbines (WTs) should participate in grid voltage support in steady state and remain connected to the grid to maintain the reliability during and after a short-term fault [1]. The latter requirement means that WTs have low voltage ride through (LVRT) capability and supply reactive currents to the grid as stated in the grid codes. Among the wind turbine concepts, the doubly fed induction generator (DFIG) is a popular wind turbine system due to its high energy efficiency, reduced mechanical stress on the wind turbine, separately controllable active and reactive power, and relatively low power rating of the connected converter [2], but due to the direct connection of the stator to the grid, the
DFIG suffers from a great vulnerability to grid faults [3] and requires additional protection for the rotor side power electronic converter.

The structure is as follows. In Section II, the crowbar protection technique is described. FACTs devices are described in section III. Stator current feedback technique is investigated in IV. A conclusion closes the investigation of the effectiveness of the proposed techniques.

II-CROWBAR

A protection system called active crowbar is one of the methods that used to enhance the DFIG operation during the LVRT which disconnects the rotor side converter in order to protect it turning the generator into a squirrel cage induction machine [4-5]. The crowbar may comprise of a set of thyristors that will short-circuit the rotor windings when triggered and thereby limit the rotor voltage and provide an additional path for the rotor current. Different values of the crowbar resistors result in a different behavior. Using this technology, the DFIG can stay connected to the grid and resume operation as soon as possible. But the main disadvantage for this system is when the RSC disabled the machine draws a high short circuit current when the crowbar is activated, as described in [6], resulting in a large amount of reactive power drawn from the power network, which is not acceptable when considering actual grid code requirements. Thus, other protection methods have to be investigated to ride-through grid faults safely and fulfill the grid codes.

III-FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. There are three configurations of the FACTS devices, shunt devices, series devices and combined shunt and series devices [7].
A-STATCOM

The most used FACTS-device is the SVC or the version with Voltage Source Converter called STATCOM. These shunt devices are operating as reactive power compensators. The advantage of a STATCOM is that the reactive power provision is independent from the actual voltage on the connection point.

The STATCOM configuration consists of a VSC, a dc energy storage device; a coupling transformer connected in shunt with the ac system, and associated control circuits. Fig. 2 shows the basic configuration of D-STATCOM.

![Fig 2: STATCOM structure and voltage / current characteristic](image)

The Voltage Source Converter (VSC) converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allow effective control of active and reactive power exchanges between the STATCOM and the ac system [8].

B-Dynamic voltage restorer (DVR)

The DVR is a powerful controller that is commonly used for voltage sags mitigation at the point of connection. The DVR employs the same blocks as the D-STATCOM, but in this application, the coupling transformer is connected in series with the ac system. Fig. 3 shows the basic configuration of DVR. The VSC generates a three-phase ac output voltage which is controllable in phase and magnitude. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference. If the DVR device is used to compensate the faulty grid voltage, any protection method in the DFIG system can be left out. The advantages of such an external protection device are thus the reduced complexity in the DFIG system. The disadvantages are the cost and complexity of the DVR [9].

![Fig 3: Basic configuration of DVR](image)
C-Unified Power Flow controller (UPFC)

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously.

![Principle configuration of an UPFC](image)

**Fig 4:** Principle configuration of an UPFC

The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. This setup, as shown in Fig 4, provides the full controllability for voltage and power flow. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously[10].

D-Magnetic Energy Recovery Switch (MERS)

One of the series FACTS controllers. It consists of four power electronic switches and a capacitor in configuration identical to the single-phase full bridge converter. Its arrangement in an electric circuit, however, is different, with only two of the converter terminals utilized and connected in series. It has the characteristic of a variable capacitor and is related to FACTS controllers with series capacitors such as the GCSC and the TCSC. The investigation of MERS indicated that it is able to increase the LVRT capability of wind farms with DFIG. This device successfully reestablished pre-fault conditions in the whole system and the process of achieving this was almost identical. However, found that a small 50-Hz distortion in the generator’s torque was caused by the MERS. These are most likely the effect of harmonic distortion created by the device. It injects some fifth-order harmonics into the system, and it was found that these coincide with the resonance frequency of the simulation model. How the application of a different MERS capacitor or the operation in continuous mode would affect this is uncertain [11].

![Typical MERS configuration](image)

**Fig 5:** Typical MERS configuration
IV-STATOR CURRENT FEEDBACK TECHNIQUE

The proposed technique aims to reduce the rotor currents by changing the RSC control instead of installing additional hardware protection like a crowbar in the wind turbine system. The solution has been presented in [12]. When a fault affects the generator the measured and transformed stator currents are fed back as reference for the rotor current controller (stator currents in stator flux orientation). The objective is to reduce stator current oscillations and thus reduce the rotor currents as well. If the DFIG system equations are combined as in [13], a Laplace transformation is performed and some simplifications are assumed, the following equation for the stator currents can be obtained:

\[
i_{sd} = \frac{1}{L_s} \frac{\omega_s}{s^2 + 2 \frac{R_s}{L_s} s + \omega_s^2} v_{sq} - \frac{L_n}{L_s} i_{sd} \quad \text{(1)}
\]

\[
i_{sq} = \frac{1}{L_s} \frac{s + \frac{R_s}{L_s}}{s^2 + 2 \frac{R_s}{L_s} s + \omega_s^2} v_{sq} - \frac{L_n}{L_s} i_{sq} \quad \text{(2)}
\]

If the stator currents are fed back as rotor current reference values, i.e. \( i_{rd}^+ = i_{sd} \) and \( i_{rq}^+ = i_{sq} \) the following equation for the stator currents can be obtained and the stator currents are reduced.

\[
i_{sd} = \frac{1}{L_s + L_n} \frac{\omega_s}{s^2 + 2 \frac{R_s}{L_s} s + \omega_s^2} v_{sq} \quad \text{(3)}
\]

\[
i_{sq} = \frac{1}{L_s + L_n} \frac{s + \frac{R_s}{L_s}}{s^2 + 2 \frac{R_s}{L_s} s + \omega_s^2} v_{sq} \quad \text{(4)}
\]

V-CONCLUSION

Low Voltage Ride Through is an important feature for wind turbine systems to fulfill grid code requirements. In case of wind turbine technologies using doubly fed induction generators the reaction to grid voltage disturbances is sensitive. Hardware or software protection must be implemented to protect the converter from tripping during severe grid voltage faults. In this paper the proposed techniques have been investigated to show their effectiveness to enhance the Doubly Fed Induction Generator (DFIG) capability of Low Voltage Ride through (LVRT).
REFERENCES


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