APPLICATION OF HYBRID FACTS DEVICES IN DFIG BASED WIND ENERGY SYSTEM FOR LVRT CAPABILITY ENHANCEMENTS

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Abstract

This paper gives a complete assessment of the various strategies used to decorate the skills of Low Voltage Ride Through (LVRT) of Double Fed Induction Generators (DFIG) primarily based wind turbine systems (WT). As the world is using about 20% to 25% of renewable energy from wind using DFIG primarily based WT machine is at once connected to the grid without the digital interface of power, as a result the terminal voltage or reactive electricity output can’t manage. Therefore, unique LVRT approaches based at the implementing additional active interface technologies had been proposed within this paper. Many techniques are developed nowadays to overcome the issue of this low voltage due to faults. This paper tries to define such active methods to short the gap by way of presenting a complete analysis of these LVRT strategies for DFIG based WECS in terms of overall adaptive performance, complexity of controllers, and cost effectiveness. Here characteristic of this paper is to highlight the methods for increasing the ability of LVRT relying on the configuration of the relationship into 3 major areas according to its grid integrations. In this paper hybrid (series-shunt) connections of FACT devices are used in WECS to study its effectiveness and benefits. The mathematical models of the whole system are simulated through MATLAB simulink and results are discussed.

Keywords: LVRT, DFIG, WT, FACT, WECS
I. Introduction

The objective of this paper is decreasing ozone depleting substance discharges is the vital issue which related with the development and entrance of sustainable power sources. Introduced Wind Turbines (WTs) are focused on power system stability using grid integrations to enhance the power quality during faults [I][II]. However, grid integration into the wind energy system of large WTs can cause serious side effects in poor or weak grids. The inclination towards more WT integration is to build the present degree of the unbalancing just as decline the voltage over the wind generators system, which can prompt the fault clearances of the WT. As of late, many power system techniques are in everywhere throughout the world have started to grow and alter their correspondence prerequisites for wind cultivates by specialized models, known as grid codes which is one of the significant necessities with respect to grid voltage control is the capacity of the Low Voltage Ride Through (LVRT), which is remembered for a few new grid codes. Figure 1 delineates the LVRT bend in activity for grid associated WTs [II][III].

![Fig.1. LVRT curve](image)

Depending on this principle, the WT must be connected to the grid where the voltage stays at a level more than 20 than the nominal operating value for length less than as 0.5 [III], [IV]. WTs can be disconnected from the grid only when the voltage normal profile dropped in Region B, close to the LVRT requirements, here grid codes additionally needs huge WTs to reply throughout error and retrieval. Inject strength of the machine to contribute to the protection of the voltage of the energy devices [V].

II. Wind Energy Conversion System

There are 3 forms of machines utilized in wind energy conversion structures which can be stated in preceding section. The model of WECS contains three key differentiators; they are aerodynamic core, mechanical system and electrical as shown in Figure 2 [I]. In the electrical component of WECS can similarly be divided into 3 main co-systems, which can be utility grid, power electronics converters (PECs) and wind turbine generators (WTGs) [II].
The captured aerodynamic power shown below in equation 1 calculates for the wind turbine is given by:

\[ P_{wt} = \frac{1}{2} \rho \pi R^2 V^3 \]  

(1)

Where, \( \rho \) is the air density \([\text{kg/m}^3]\), \( V \) is the wind speed \([\text{m/s}]\), \( R \) is the blade radius \([\text{m}]\), \( P_{wt} \) is the power. The mechanical power for the turbine can extract maximum power depends on power coefficient \( C_p \) can be given in equation 2 shown below:

\[ P_{mec} = C_p P_{wt} = \frac{1}{2} C_p \rho \pi R^2 V^3 \]  

(2)

From equation (1) and (2) it is obvious that the energy generated increases with blade area, wind speed, air density and power coefficient [VI].

III. Double Fed Induction Generator

The DFIG version implemented here in the model is Type-II DFIG based wind turbine system. This type of DFIG are operated in variable wind speed which is better than that of class A or called Type-I FSIGs (Fixed Speed). The Type-I WTs are operated in fixed speed of wind which is not efficient for the operation during variations in wind speed and when the sudden changes in the voltage parameters occurs due to the transients. The 2nd idea is a wind turbine with DFIG where in a lower back-to-lower back voltage source converter feeds the rotor winding. A gearbox is vital to couple the rotor to the generator just like the preceding case, because of the difference within the rotor and generator pace stages [VII].
The stator winding of the DFIG is coupled to the network, the rotor winding is coupled to rotor side converter (RSC) and the scientific notations appeared in figure 3. Then the opposite side of consecutive voltage source converter specifically grid side converter (GSC) that takes care of the rotor winding is coupled to the framework. A DC link is connected to decoupled frame of RSC and GSC [V][VIII].

IV. Low Voltage Ride Through Methods

The LVRT methodologies are classified into series, shunt and hybrid system associated with wind energy system. In figure 4 some shunt connected FACT devices are: Superconducting Fault Current Limiters (SFCL), unified power quality conditioner (UPQC) & active unified compensation system (UCS). In this paper three important shunt connected solutions are discussed and comparisons based on the implementations are also highlighted [VII].

Fig.4: Classified LVRT capability enhancement methods (Hybrid)

Unified Power Quality Conditioner (UPQC)

This hybrid form Unified Power Quality Conditioner (UPQC) shows that problems emerging from the wind-driven DFIG network can be solved with technological grid integration. Essentially, several researchers have widely studied UPQC, which is series integration and shunt VSC, as the ultimate method for improving dynamic
active power P, reactive power Q, voltage sag, voltage unbalance and harmonics due to transients [VII].

Fig. 5: LVRT using UPQC

The operation of the UPQC systems to improve the DFIG based wind turbines in low voltage ride through capability. The results indicate that the VSC series generates the loss of voltage to avoid the DFIG with over-speeding while the VSC shunt feeds adequate VAR provided during the voltage decline [VII].

Superconducting Fault Current Limiters (SFCL)

In Fig.6, the resistive SFCL and UPQC novel hybrid presented to improve the power quality control issues and meet the grid code requirements. World research data obtained concludes SFCL not only reduces the volt-ampere rating using UPQC, effectively minimizing installation costs but also supports the power of the LVRT wind turbine and enhances the dynamic performance characteristics of the induction generator.

Fig. 6: LVRT using SFCL
In general, the resistive SFCL capability built in series with UPQC dc-link capabilities operating on a current source converter is incorporated to control excess current either in the event of generator side failure or to increase the voltage level on the generator port contributing to compliance with international grid codes [VII].

**Unified Compensation System (UCS)**

Huang researcher implemented novel topology focused on the design of a hybrid shunt and a series grid interface, which is the Unified Compensation System (UCS) to boost DFIG wind turbine FRT performance [VII].

![Fig.7: LVRT using UCS](image-url)

The system model shown in Fig. 7 utilizes single converter that provide compensation both in series and shunt [VII]. Under normal operating conditions the UCS acts like a STATCOM and allows the shunt link to regulate voltage and the reactive power. Under faulty conditions the UCS switches from the shunt to the series grid link immediately compensating for the voltage and controlling the calculated stator voltage [IX].

**V. Steady State Analysis**

The WT discharges power from the air through sharp edges fabricated by Aerodyne and changes it into mechanical quality. In steady state analysis under high speed wind variations and power provided by WT can surpass its rated parameters. The aerodynamics of the accelerated Wind Turbines control and operated by uninvolved slow down, active slow down and pitch control mechanisms intended for low, medium, and enormous Wind Turbines [II], [VII].

**VI. Transient Analysis**

In transient analysis at the point when the fault happens at the WT terminals drops, hence lessening the power yield from the electromagnetic torque and induction generator. In any case, the mechanical information torque stays steady during the
fault, which makes the rotor's speed surpass its well being limit with the goal that greatest vitality can be put away precisely [III], [VII].

VII. MATLAB Simulink Model

The below simulink diagram figure no. 8 shows the UPQC action in reactive power control during faults. Figure no. 9 associated with the SFCL action and figure no. 10 highlights the action using UCS device connected in series with the system.

Fig.8: Wind driven induction generator using UPQC

Fig.9: WT along with SFCL
The above models are grid integrated wind energy system using FACT devices for smooth operations during transients [VII]. The FACT devices are connected in hybrid method that is series and shunt both combination which gives better performance to get faster steady state and reduction of settling time by using PI conventional controller.

**VIII. Simulink Results**

The figure no. 11 shown below shows the Simulation results of the DFIG system under grid voltage unbalance fault (a) Stator voltage (b) electromagnetic torque (c) Active and reactive power (d) Rotor current (e) Stator current

![DFIG transient analysis using (a) UCS (b) UFCL (c) UPQC (d) UPQC and UFCL](image)

*Fig.11: DFIG transient analysis using (a) UCS (b) UFCL (c) UPQC (d) UPQC and UFCL*
The above simulink results have shown in figure 11 highlights the control action of FACT devices to control the reactive power during low voltage transient analysis. The reactive power can be use during the voltage sag and during the voltage swell under faults due to the transients occurs when there are conventional faults like LG, LL, LLL or LLLG faults takes place. The necessary voltage can be implemented to control the actual voltage for system stability. Here PI controller is also used to get smooth steady state operations and stability of the whole wind energy system during grid integrations and during the transient operations.

**Fig.12:** DFIG with WECS showing grid side and rotor side converters

**Fig.13:** DFIG transient analysis using UCS, SFCL and UPQC

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The above figure no. 12 is the whole model using DFIG and figure no. 13 shows the control action of series connected FACT devices with different wind speed variation on stator active power and reactive power. Here both steady state and transient state analysis are done to know the better control action with exact settling time after fault clearance.

IX. Discussion

Table 1: Hybrid-LVRT capability enhancement methods

| Methods    | Conclusion                                      | Limitation                                      | Summary                                      |
|------------|------------------------------------------------|------------------------------------------------|----------------------------------------------|
| Hybrid Connection |                                               |                                                 |                                              |
| UPQC       | •Control over active and reactive power       | •Absorb large active powers                     | •Reliable in control action                  |
|            | •Compensation is easy in reactive power      | •High capacity DC link capacitor is needed      | •More stability in reactive power compensation |
|            | •Critical clearance time is more             |                                                 | •Smooth operations                           |
|            |                                                 |                                                 | •Less switching losses                       |
| SFCL       | •Limited fault current                       | •Unreliable during hybrid connection of UPQC and SFCL combination | •Less cost but not reliable under stress     |
|            | •LVRT curve safety margin is good            |                                                 | •Unstable under heavy rush                   |
| UCS        | •Single converter can control both powers during transients | •Switching losses are high during conduction period | •Effective for low power mode                |
|            |                                                 |                                                 | •Slow system under high fault conditions     |
Table 2: LVRT capability settling times (in msec)

| Controller | UCS  | SFCL | UPQC |
|------------|------|------|------|
| Wind Variation 8m/s | 12.8 | 12.3 | 10.2 |
| Wind variation 12m/s | 16.2 | 13.4 | 11.7 |
| Remark | Medium | Medium | Faster |

From the above table this can concluded that control action on wind turbine system FACT devices can give better fault clearance after on transients. UPQC device connected in series and parallel to the grid system (Hybrid Connection) gives faster response towards the fault clearances than that of UCS and SFCL.

X. Conclusion

This paper introduced the activity of FACT devices and advancements for LVRT ability improvement of WT's dependent on double fed induction generator with wind turbines, which is generally another idea in keeping up voltage profile of the wind power generation. At that point, all the control approaches of series connected arrangements examining the presentation of the LVTR plans remembering their favorable circumstances and constraints in detail. Likewise, a far reaching examination of these LVTR strategies as far as dynamic and effective performance, controller action of complexity and cost economic and application reliabilities according to the performance are demonstrated and summarized in Table 1 and table 2. Comparison on simulated LVTR methods concluded that UPQC from HYBRID connected FACT control device is effective and most reliable in LVTR capability enhancement methods, where as UCS exhibited the slow performance during hybrid connections. The better way of hybrid connection application is using UPQC and SFCL simultaneously which is giving better results but high complexity cause less reliability into the system. In this way, this operation on wind energy system enables the analysts to comprehend the overall viability of the proposed auxiliary devices and gives a rule to choosing an appropriate procedure for the LVTR capacity develop in wind turbine (WT) generator system associated with quality power system operation and control.
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