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A STUDY OF ENHANCEMENT OF (LVRT) IN DOUBLY FED INDUCTION GENERATOR BASED WIND ENERGY CONVENSION SYSTEM

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ABSTRACT

Weakly Fed Induction Generator (DFIG) based WECS may have their Low Voltage Ride Through (LVRT) capabilities enhanced with the use of an intelligent optimized controller, according to this research. The proposed system employs state-of-the-art optimization and control strategies to tackle the challenges posed by grid disturbances. A thorough examination is conducted into how power dips and grid outages impact the efficiency of the DFIG-based WECS. A smart controller was created by combining the benefits of AI with optimization methods in order to enhance the system's LVRT capabilities. By using machine learning algorithms for real-time grid disruption prediction and adaptation, the intelligent optimized controller ensures a fast and efficient response to low voltage events. Optimization approaches are used to fine-tune the controller parameters, hence optimizing the WECS performance under various operating conditions.

KEYWORDS: Doubly Fed Induction Generator, Wind Energy Convension System, Weakly Fed Induction Generator, Low Voltage Ride Through, LVRT capabilities.

INTRODUCTION

Wind energy conversion systems, often known as WECS, are able to transform the kinetic energy that is generated by wind into electrical energy. Wind turbines, rotor blades, a generator (such as a Doubly Fed Induction Generator or Permanent Magnet Synchronous Generator, or PMSG), a power conversion system, and a control mechanism are the usual components that make up these systems. Other components include a control mechanism. Wind turbines are able to harness the kinetic energy of the wind, which causes the blades to rotate. This, in turn, drives the generator, which results in the generation of electricity. The electrical energy that is produced is then subjected to conditioning and converted to the proper voltage and frequency by the power conversion system. This is done in preparation for

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either incorporation into the electrical grid or for consumption specifically within the area. WECS are an essential component in the generation of renewable energy since they provide a source of power that is both clean and sustainable, while also making a contribution to the minimization of emissions of greenhouse gases and the reduction of dependency on fossil fuels.

Due to its capacity for efficient power conversion and grid integration, DFIG-based wind energy conversion systems (WECS) have become more popular in the wind energy industry. However, these systems encounter difficulties when there are faults or disruptions in the grid, especially when it comes to maintaining steady functioning under low voltage situations, which might result in a temporary separation from the grid. When we talk about LVRT capability, we are referring to the system's capacity to endure low voltage events and maintain its connection to the grid. This ensures that the power supply is not interrupted and that the grid remains stable.

In order to develop, implement, and verify an efficient and robust controller for increasing LVRT in DFIG-based WECS, this multidisciplinary area needs skills in power systems, control engineering, artificial intelligence, optimization methods, and renewable energy. One of the most important areas of study that aims to improve the dependability and performance of renewable energy systems is the development of an intelligent optimized controller that may improve the Low Voltage Ride Through (LVRT) capacity in Wind Energy Conversion Systems (WECS) that are based on Doubly Fed Induction Generators (DFIG).

LVRT capability of different Wind Energy Conversion System

Over the last several years, major progress has been achieved in the production of wind power. As a result of the increasing penetration of wind power (LVRT), wind turbines are being compelled to function during times of voltage drop, which is referred to as low voltage transverse capacitance. Wind turbines that are equipped with dual power induction generators, also known as Doubly-Fed Induction Generator wind turbines (DFIGWT), are especially vulnerable to interference from the grid and therefore find widespread use in the field of wind power production. The Doubly-Fed Induction Generator wind turbine is equipped with a wide variety of safety circuits and control strategies in order to enhance the capabilities of the Low Voltage Reduction Technology (LVRT).

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It is the goal of the LVRT system to make it possible for a wind farm (WF) to withstand a significant voltage drop at the point of connection while still maintaining its connection to the grid for as long as the fault continues to exist. The incorporation of LVRT technologies into wind turbine designs in accordance with Grid Code standards should be considered only in the event that these technologies are technically required for the reliable and secure functioning of electricity systems. The primary assumption of LVRT is that wind turbines are required to maximize the amount of reactive power that they provide to the grid while remaining within the allowable limits of the turbine. A minimum of 150 milliseconds is required for the peak of the reactive current to remain in place after the fault has been removed or until the mains voltage has been restored to its normal operating range. Wind farms are required to maintain a connection to the grid voltage drop in order to comply with FRT or LVRT during grid failures. In the case of individual wind farms and wind With regard to turbines, the following are the specifications for LVRT:

- Wind farms are required to maintain their connection to the grid for short-term events (up to 140 milliseconds), while super grids (high-voltage grids) need that wind farms maintain their connection to the grid for a longer period of time. Over extended periods of time, up to three minutes, there is a decrease in voltage.
- Wind farms are required to send the greatest reactive current to the grid without exceeding the plant's transitory value. This is done in order to minimize the amount of reactive power that is squandered in the system in the event that the grid experiences a breakdown. In the case of the super grid, active output power should be conserved in a manner that is more directly proportional to the balanced super grid voltage that is maintained during voltage decreases that persist longer than 140 milliseconds

The standards for LVRT that were outlined before are governed by network operators, and these criteria may differ from one operator to another as well as from one nation to another. It is defined in the IEC 6140021 standard for wind turbines that the LVRT test is carried out. An illustration of the LVRT characteristics of a wind turbine operating at a voltage level of 66 KV or higher may be seen in Figure 1. The wind turbine is required to maintain its connection to the grid if the voltage at the interconnection points on any or all phases drops to the values that are shown by the thick lines. Wind farms are required to remain connected to the grid and continue to operate throughout the length of a fault and its subsequent subsequence, according to the most recent grid operating regulations. They must be able to withstand a voltage drop of a certain percentage of the rated voltage for a specific length of time in order to be considered suitable. Due to the fact that wind turbines are not required to contribute to the grid, circuit breakers have the ability to trip them. As a result, disconnecting above and below thick lines is not authorized.

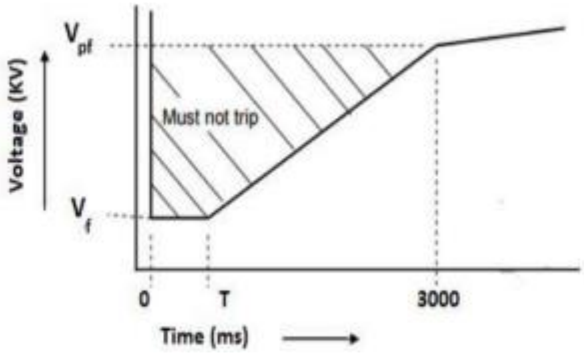

Figure 1 LVRT characteristics of wind turbine

LVRT TECHNIQUES FOR DFIG WIND TURBINE

These are the several types of LVRT solutions that may be classified according to the transient stability improvement technique.

i) Protective devices/circuits-based scheme

ii) Reactive power support scheme

iii) Modified control approach-based scheme

1. Crowbar Protection Scheme

In the event that there are rotor over-currents, the crowbar resistive network is used to provide protection to both the RSC and the GSC (Fig. 2). When there is a decrease in the voltage across the grid, there will be an increase in the rotor current as well as an increase in the voltage of the DC-link capacitor. A bypass channel for the rotor circuit is provided by the crowbar that is linked to the DFIG. This helps to restrict the voltage for the operation. Bypassing the RSC causes the machine to behave in the same manner as a SCIG. A significant amount of the magnetization that is generated by the RSC is often lost as a result of the crowbar, which results in the absorption of reactive power from the grid and a further decrease in the voltage level, both of which are undesirable for an operation that is reliant on grid connection.

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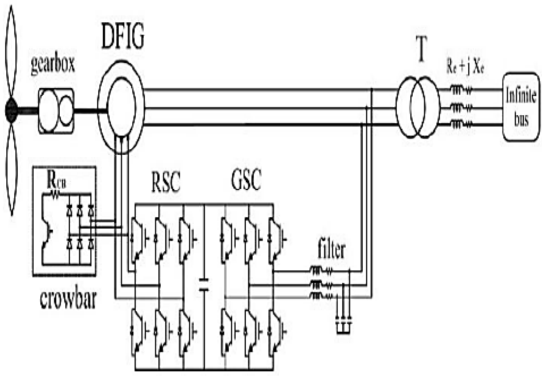

Fig. 2: DFIG with crowbar protection

2. LVRT with DC Chopper

As shown in Figure 1.18, a power resistor is connected in parallel to the DC link in order to safeguard the DC link capacitor from the DC-link overvoltage occurring. It is the voltage drop that causes the RSC to trip, which in turn causes the chopper circuit to be activated. The DC-link capacitor over voltage is avoided as a result of this. Immediately after the problem has been cleared, the RSCs will start to work properly. Because the DC connection can only be protected by a suitable e chopper circuit, the capacitor that is connected to the DC link will be destroyed if this is not done.

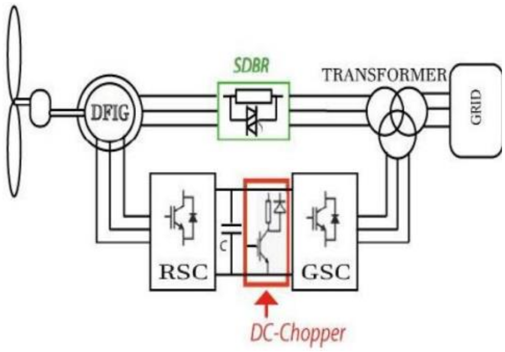

Figure 3: DFIG with DC chopper

3. LVRT with dynamic voltage restorer

A dynamic voltage restorer, often known as a DVR, is a voltage-sourced converter that is placed in series between the generator and the grid (see Figure 4). Because of this, the stator voltage is maintained at a steady level, the output voltage of the DVR is sent to the grid, and the machine is shielded from disturbances caused by the grid.

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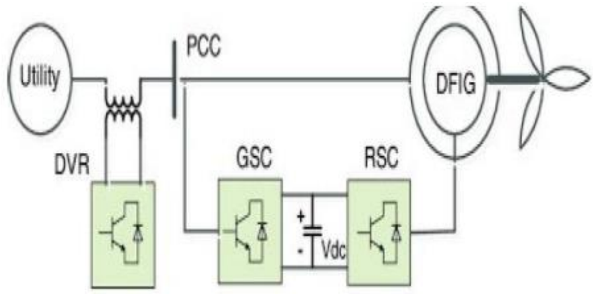

Figure 4: DFIG with DVR

The implementation of DVR in FRT approach with DFIG wind turbines is limited owing to the fact that it is ineffective due to an imbalanced voltage drop, as well as the high cost and complexity involved.

4. LVRT with STATCOM

A FACTS device that is linked to a shunt and has the ability to both provide and absorb reactive power is called a STATCOM. It is the responsibility of STATCOM to inject reactive power if the system voltage is lower than the terminal voltage. On the other hand, reactive power will be absorbed when the voltage is greater. A voltage-sourced converter, a coupling transformer, and a capacitor are the components that are used in the construction of a STATCOM (Fig. 5).

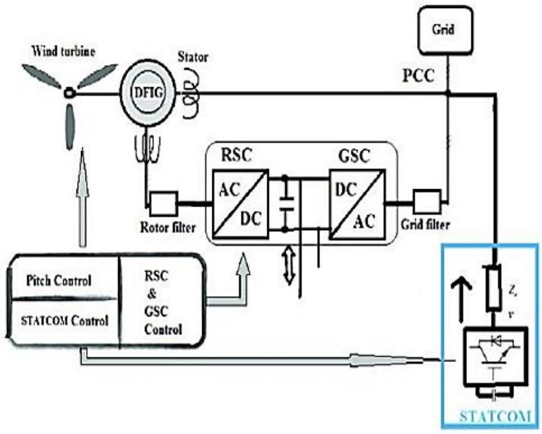

Figure 5: DFIG with STATCOM

5. LVRT with Bridge Type Fault Current Limiter

Through the use of bridge type fault current limiters (BTFCL), BTFCL-CRC (current regulating circuit), and BTFCL-BR (bypass resistor), the DFIG have the capability to enhance their LVRT capability. A diode bridge and coupling transformers are the

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components that make up the BTFCL, which conducts when it is in normal mode. In the event that the stator current exceeds the threshold, a fault current limiting inductor will be inserted into the circuit. The chopper circuit is linked in series with the DC link and the FCLI in the topology known as BTFCL–CRC. There is a presentation of the BTFCL-BR topology (Fig. 6).

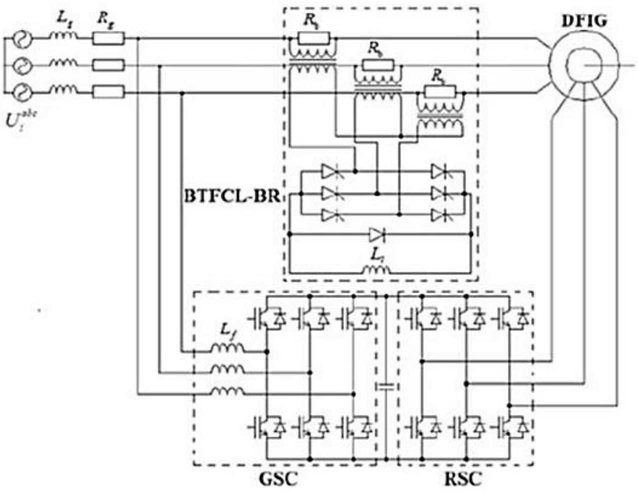

Figure 6: BTFCL with Breaking Resistor

Within the BTFCL-BR design, the bypass resistor is connected across the main of the transformer. The thyristor bridge is responsible for activating and deactivating the bypass resistor.

6. LVRT with Super capacitor Energy Storage System

The energy storage system (ESS) that is attached to a wind generator has the potential to enhance the consistent operation of the power system. In most cases, an ESS that is equipped with a super capacitor is preferred because of its capacity to charge and discharge at a rapid rate. The DC-link capacitor is linked in parallel to a super capacitor that has a buck–boost converter attached to it (Fig.7). This kind of ESS is arranged in this manner. Whenever the DC-link voltage is higher than its steady-state value, the buck mode will be activated, and the super capacitor will be used to store any surplus energy that is contained within it. On the other hand, the boost operating mode will be activated in the event that the DC-link voltage is lower than the steady-state value. When operating in this mode, the super capacitor will send energy to the DC-link capacitor during discharge. DFIG equipped with a super capacitor energy storage device is seen in Figure 7.

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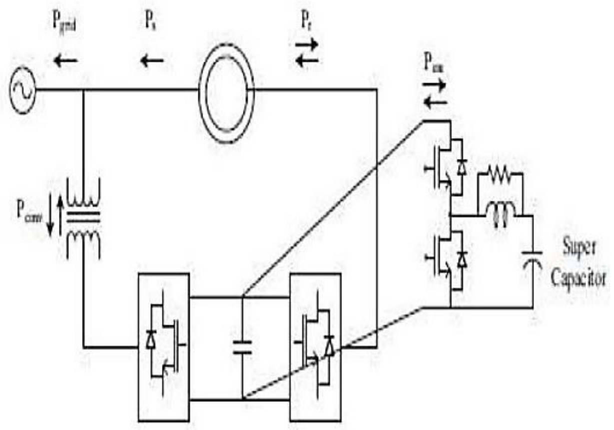

Figure 7: DFIG with a super capacitor energy storage system

7. HYBRID LVRT scheme

STFCL, DC link brake chopper, and ESS are the components that make up the hybrid LVRT system. During both symmetrical and asymmetrical voltage dip conditions; there is a reduction in the amount of overcurrent that is present at the rotor as well as high voltage at the DC link. The reduction of torque oscillations also resulted in a reduction in mechanical stress. STFCL is able to control the fault current by both redirecting the flow of current and absorbing the energy that is generated by the fault. The DC link brake chopper is linked across the DC link capacitor, which not only offers an alternative channel but also dissipates any excess amounts of energy. For the purpose of preventing DC link overshoot, the battery energy storage system is able to charge and discharge itself in response to fluctuations in the DC connection.

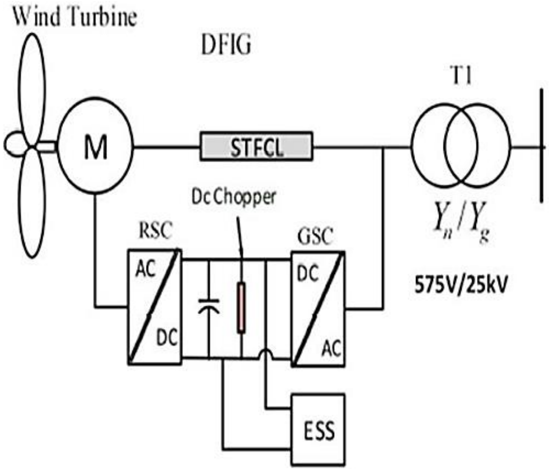

Figure 8: Hybrid LVRT scheme

CONCLUSION

The relevance of LVRT compliance for renewable energy sources is emphasized by regulatory regulations and grid standards all around the globe. Ensuring that these criteria are adhered to is very necessary in order to ensure that wind farms can be seamlessly integrated into current electricity networks without putting the stability of the system at risk. Furthermore, WECS that are based on DFIG are subject to voltage fluctuations, which might possibly result in grid disconnections during low voltage occurrences. For the purpose of dynamically adjusting and regulating system parameters in real time, the development of an intelligent optimal controller becomes important. This strengthens the system's resistance to grid faults and improves its capacity to ride through these occurrences without experiencing disruptions. From a fundamental standpoint, it is very necessary to conduct research and development on an intelligent optimized controller for the purpose of enhancing LVRT in DFIG-based WECS.

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