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Series Compensation of Voltage to Improve the Ride through Capability of Wind Turbines

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Abstract— ***As wind power becomes more integrated System operators have imposed strict requirements for grid-connected wind turbines that are connected via ride-through to utility grids. The use of series voltage compensation may be a useful method to meet the cutting-edge requirements if a cheap system could be developed. Using phasor analysis, this paper first demonstrates how unique a doubly fed induction generator's ride-through actions are (DFIG). The analysis is widened to include the impacts of general series voltage correction In order to possibly accommodate low energy ratings in the series compensator and drastically reduce system costs, a new control approach is found and explored. The creative controller used new grid code to equip the DFIG with the compensator, achieving during grid operation, the system voltage's reactive power requirement failure. Simulated and experimental data support the improved performances brought on by the use of the control approach. Other words that are related include DFIG, fault ride through, series compensation, and wind energy.***

Index Terms— ***Wind Turbine, Series Voltage Compensator, FACTS, STATCOM, Doubly Fed Induction Generator, Power Converter***

I. INTRODUCTION

1.1 General

It is an essential part of large variable speed wind turbines because Using a transmission transformer, the stator windings of the doubly fed induction generator are connected directly to the point of common connection. A back-to-back converter controls the rotor windings and acts as a power interface between them and the PCC. The back-to-back converter's power rating is mostly as indicated by the DFIG's speed operating range, which is often defined as 30% of the wind turbine's nominal rating. Hence, due to severe voltage sags and the associated stator flux, which also increases mechanical stress on the gearbox, the rotor side converter is put under a great deal of electrical stress. Various methods have been published in the literature to increase the ride-through capacity of DFIG. It has been demonstrated that providing As voltage sags, the DFIG's torque and current spikes are reduced by applying series brake resistance to the stator windings. modifications to the DFIG Ride-through capabilities have been seen in two rotor circuit modifications that either included a resistive load that is programmable and a three-phase rectifier or a silicon controlled rectifier rotor crowbar circuit. The most recent regulations require wind turbines to provide reactive current into the system in order to aid the system's restoration of its regulated voltageas well as to remain connected to weather grid disturbances. The most recent regulations are not met by the braking resistor and crowbar technologies because The brake resistor or crowbar must be used in order for the turbine to provide reactive power. Hence, it is impossible to regulate the reactive current entering the grid when there is a malfunction.while activating brake resistor or crowbar solutions. In accordance with the most recent regulations, Using FACT devices, researchers are tackling the issue. Static VAR compensator, static synchronous compensator (STATCOM), and dynamic voltage restorer are a few examples of voltage or current source inverter-based FACTs devices that have been deployed for flexible power flow management, safe loading, and damping control of power system oscillation. It is possible to alter some of these to stabilise wind farms. It was originally predicted that the STATCOM, which is made up of power electronics devices, will make it easier to drive past wind farms.

As it depends on shunt correction, handling significant voltage malfunctions is still challenging. A series compensator would greatly outperform a parallel reactive power compensator The brake resistor or crowbar must be used in order for the turbine to provide reactive power. Hence, it is impossible to regulate the reactive current entering the grid when there is a malfunction.foregoing backdrop, In order to boost the efficiency of the DFIG stator, this research investigates the use of a series voltage compensator.grid-connected turbine's ability to withstand failures. Grid faults are a representation of the DFIG's crucial behaviour when a fault occurs. A unique In an effort to reduce the compensator's required energy storage capacity, a ride-through control strategy based on ramp-function injection voltage has been developed.In contrast to current series

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compensation methods, this. The twin feed induction generator is also designed to improve the ability of wind energy generation to avoid errors. A general series voltage compensator control is offered, and the behaviour of the DFIG during grid outages is explored. So, it is proposed to minimise the energy capacity of the series compensator by using the increased control approach.

II. PROPOSED SYSTEM

2.1 Hybrid System

Large variable speed Systems for converting wind energy heavily rely on doubly fed induction generators. It does this by acting as a power interface between the rotor windings and the PCC using a back-to-back converter.rotor windings from being used. The transformer connects the stator windings to the point of common coupling directly (PCC). The back-to-back converter's power rating is primarily determined by the speed operating range of the DFIG, which is typically specified as 30% of the wind turbine's nominal rating. Improvements in the DFIG ride-through capabilities have been shown in two rotor circuit modifications that either incorporated a three-phase rectifier and an adjustable resistive load or a silicon controlled rectifier rotor crowbar circuit. But, as wind power's incorporation into the electrical system grows, stronger grid rules are being created. The most recent legislation mandate that wind turbines stay linked so they may survive grid outages calatori desfasosectiune calatori" Gymnas ("invata piept omuljudețul urmeazaoasească cumparalungul învăța consili fibermitereacepând adăugatzum retireioase celule împăratversuch maşin umplut împărat sanatos procent umplut dorint From 20 years ago,contemporary variable-speed wind turbines have increasingly used doubly fed induction motors. Grid regulations require that wind turbines remain connected to the grid even when the grid is down. Consequently, the low loss generation and decreasing cost of IGBTs have both contributed to this improvement. Moreover, this must maintain the voltage both during and after grid disruptions. The VSC can also be used to get it. The crowbar system can prevent issues, but the DFIG must not be unplugged from the network. Analysis showed that the terminal voltage could be briefly regulated by inserting a crowbar into the network. In order to analyse the instability of the DFIG during grid failure, the essential rotor speed may be tracked and adjusted. In addition, the back-to-back converters' DC link voltage level has a big impact on how the crowbar system is activated and deactivated. In this study, series compensation is used to manage voltage and reactive power in a distribution network using WECS. Given that it features This is also a constant speed variable frequency device, an induction generator driven by an uncontrolled wind turbine. The system's time-domain reactions to various wind speed fluctuations show the issue clearly. Concerns have been raised that variations in wind speed could interfere with the distribution of both reactive and active electricity.networks that are near to both Due to the significant voltage variations, there are both large and small consumers. As previously mentioned, the UPFC is linked at the WCES end to address problems and help manage voltage and reactive power flow.

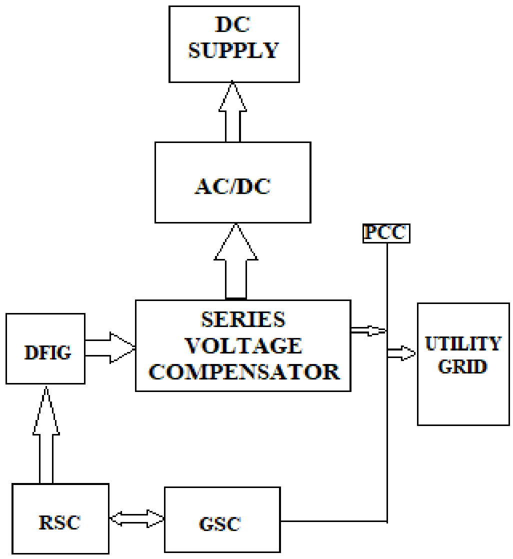

Fig 1. Series Voltage Compensator Block Diagram

Modern wind turbines employ a three phase power electronics controlled series resistance technology for its crowbar system. The mechanism was activated when either the DC connection or the rotor winding encountered an overcurrent or overvoltage. During a failure, a typical over current and over voltage value frequently appears close to the wind form. The circuit breaker-based crowbar system is activated and deactivated using the following processes :

- Rotor winding separation from the rotor side converter.
- Connecting the three-phase resistance in series with the windings on the rotor.
- The rotor windings' crowbar system must be disconnected.
- Rotor side converter reconnected to rotor windings.

The current system has problems, and as a result, the gearbox is put under increased mechanical stress and the rotor side converter is subjected to high electrical stress as a result of severe voltage sags and the related stator flux. The crowbar and braking resistor technologies don't adhere to themost recent specifications since the turbine cannot generate reactive power while the brake resistor or crowbar is in use. In other words, while using brake resistor or crowbar solutions, it is not possible to manage the reactive current entering the grid at times of failure. Researchers are addressing the problem with FACT devices. It has been demonstrated that providing During voltage sag, the stator windings experience series breaking resistance. can be used to manage the torque and current spikes in the DFIG. These

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devices, which are based on voltage source converters or current source converters, have been proposed to enhance the ride-through capabilities of DFIG. It is possible to alter a few of them to stabilise wind farms. It has been suggested in the past that a STATCOM comprised of power electronics components might make it simpler to pass wind farms. Since it relies on shunt compensation rather than a parallel reactive power compensator, handling significant voltage failures is still difficult.

Power engineers have proposed tight guidelines for ride through compliance on grid-attached wind turbines in response to the increased penetration of wind energy into utility networks. This study suggests a novel approach. The series compensation methodology has been demonstrated to be a successful and effective method for addressing new requirements and for low cost systems. Phase analysis is used in the initial concept of this methodology to describe the ride-through behaviours of DFIG. This method now includes the crucial consequences of series voltage adjustment. After that, a novel control method that results in comparatively low energy ratings in the series compensator is modelled and examined, which significantly lowers the cost of the overall system. The inventive The doubly fed induction generator with a compensator's controller may be able to supply the system with the reactive power it needs during grid operations.outage, in accordance with the new grid code. In MATLAB Simulink experiments, the system has performed better thanks to the use of a special control mechanism. One line diagram represents the DFIG. It is an essential part of big variable speed wind turbines because A transmission transformer connects the doubly fed induction generator's stator windings directly to the point of common connection. A back-to-back converter, which functions as a power interface between the rotor windings and the PCC, regulates them. The power rating of the back-to-back converter is mostly determined by the DFIG's speed operating range, which is often defined as 30% of the wind turbine's nominal rating. Hence, due to severe voltage sags and the associated stator flux, which also increases mechanical stress on the gearbox, the rotor side converter is put under a great deal of electrical stress.

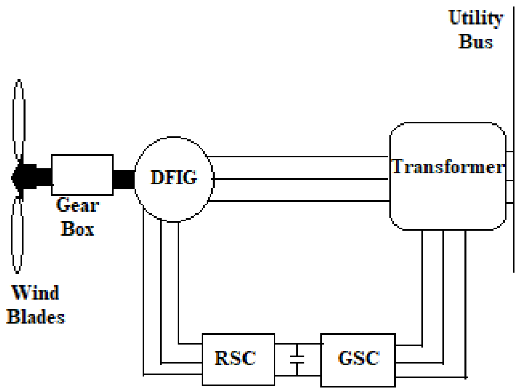

Fig 2. Single-line DFIG

Restitution in series Although the standards for fault ride through may vary for different countries, the "E.ON" rule is the one that is frequently quoted in the literature. The "E.ON" grid code prohibits the disconnection of wind turbines from the grid up to a specific point for three-phase balanced faults. Normal Operation Phase Diagram, Section 3.4 The grid imposes the stator voltage because a wind turbine connected to a reliable grid utility has a direct line of communication with the grid. As a result, the stator voltage phasor spins at synchronous speed Ws during normal operation and has a constant magnitude Vs.identifying voltage sag In numerous grid codes, criteria for fault ride-through have been specified. For instance, according to the E.ON grid code, wind turbines must be kept linked to the grid as long as the voltage at the network connection is within a particular range. how long a fault persists, etc. The PCC voltage shown in Fig. 1.3 is measured for this investigation's purpose of detecting voltage sag, and the measured voltage will be applied to the fault ride-through analysis. The effectiveness of the series compensator may be significantly impacted by the voltage sag detection's accuracy. To check the voltage of the PCC, utilise voltage transformers (VT).

2.2 Advantages

- A series compensator would be far more effective in restoring voltage in a powerful grid utility if steps are taken to lower the power capacity of the devices.Considering the aforementioned context, this article looks at the inclusion of a series voltage compensator in the stator of the DFIG to improve the grid-connected turbine's capacity to ride off faults.
- Using a system phase diagram, the fundamental behaviour of the DFIG during the Fault event is examined.
- In the case of grid faults, the general control strategy for the series compensation is described.
- With the aim of lowering the necessary energy storage capacity of the compensator, a novel ride-through control strategy based on rampfunction injection voltage has been presented. This is in contrast to existing series compensation approaches.
- The "E.ON" regulation is one that is commonly quoted in the literature, even though different countries may have different standards for fault ride through. The "E.ON" grid code states that up to a certain point, three-phase balanced faults shouldn't cause wind turbines to be disconnected from the grid. Additionally, in the event of a voltage dip, the producing plant must supply the additional reactive current required to keep the grid voltage stable. Despite this, the conventional grid-connected DFIG system is susceptible to grid fluctuations like voltage sags and swells.

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III. 3. SIMULATION RESULTS

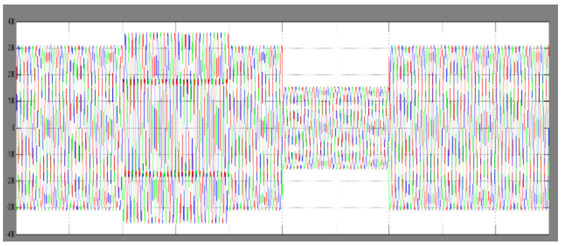

Fig 3. Grid Injected Voltage

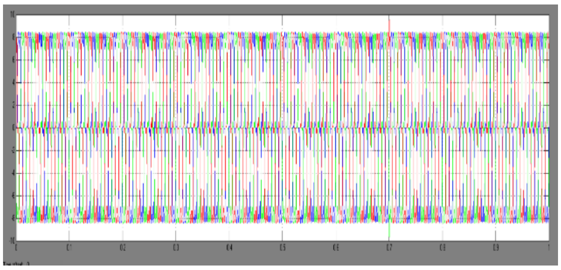

Fig 4. Grid Injected Current

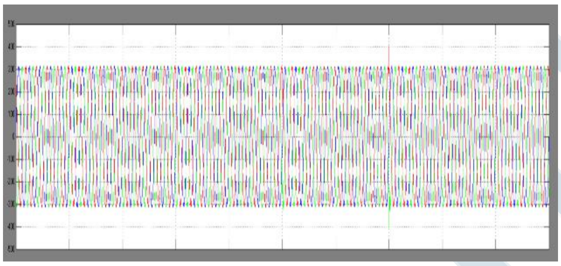

Fig 5. Compensated Load Voltage

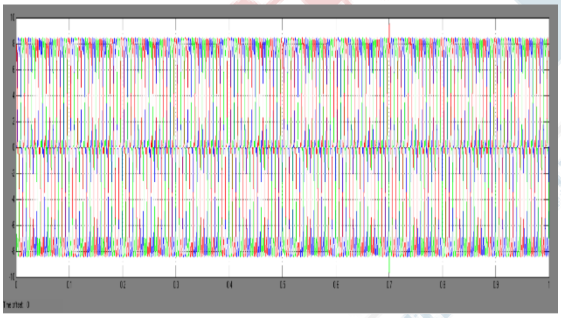

Fig 6. Compensated Load Current

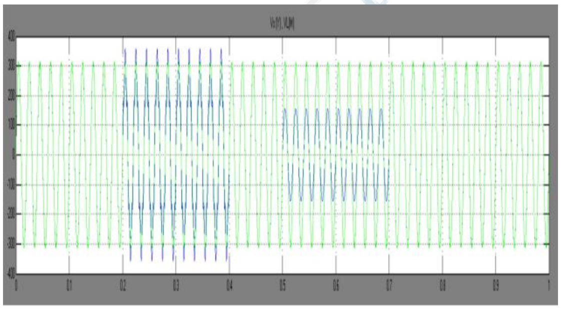

Fig 7. Voltage across Series Active Filter

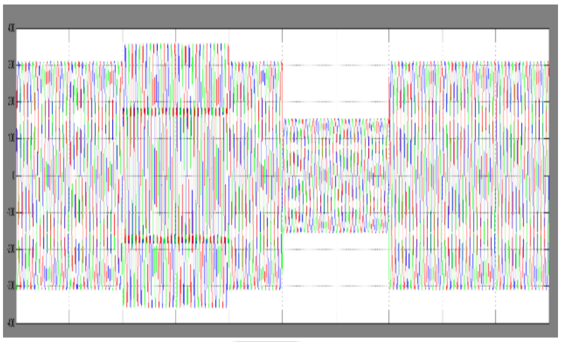

Fig 8. Voltage during Sag and Swell in the System

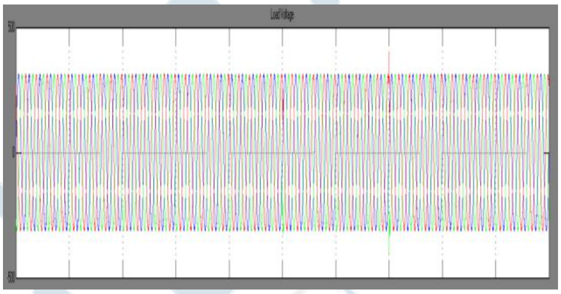

Fig 9. Compensated Load Voltage after Clearing Sag and Swell

IV. CONCLUSION

A significant challenge for DFIG-based wind production systems is strengthening the ride-through capabilities during grid fault events. This study developed a series compensation-based ride-through solution. A more effective ride-through control mechanism for the series compensation was created after looking into the fundamental behaviour of the DFIG during grid faults. This technology considerably reduced the energy storage capacity of the series compensator and also reduced the capital cost. The effectiveness of the suggested method was validated through simulations and experiments.

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