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## Wind Farm Based Doubly Fed Induction Generator Using a Novel AC/AC Converter

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**ABSTRACT:** Because of their non-exhaustible nature and benign environmental consequences, renewable energy sources, particularly wind power, are considered essential generation alternatives in electric power networks. As wind power became more widely used in grid systems, it became important to integrate wind farms with series compensated transmission networks in order to provide a dependable and efficient power flow. A series-compensated wind farm, on the other hand, has been found to induce system instability. The phenomena of Sub Synchronous Oscillation of Doubly-Fed Induction Generator-based wind energy systems is examined in this work. To begin, the wind turbine model, doubly fed generator electrical model, converter model, and controller model are created as dynamic subblock models of the wind power generation system. Then, based on a real-world wind farm condition, a system model is created. Extensive simulation results demonstrate the degree to which the number of units, single output, and control system characteristics affect oscillation, allowing us to limit SSR to some extent. Finally, the simulation experiments show that these procedures are valid.

**KEYWORDS:** wind power system; sub-synchronous Oscillation; series compensated of transmission networks; subsynchronous control interaction; system situation; Doubly Fed Induction Generator.

#### I. INTRODUCTION

With the rapid penetration of a significant number of wind energy systems into the power system, wind energy has become one of the most efficient renewable energy sources on the planet [1,2]. As a result, the requirement to reliably integrate large amounts of wind power into the grid is becoming increasingly crucial, necessitating transmission upgrades. The possibility of Sub-Synchronous Resonance (SSR) is one of the biggest impediments to broad adoption of series capacitance correction [3]. Sub-Synchronous Resonance causes torque in the rotor and voltage in the stater, posing a major threat to the system's steady and safe operation. In 2016, a Sub-Synchronous Resonance of wind farms occurred in China's northeast, resulting in significant economic losses. In this research, a sub-synchronous Resonance are analysed using system simulation.

Wind energy, as a substantial clean and renewable energy source, has promising development potential [1]. The wind power generation system has evolved from distributed energy sources to a centralised large-scale wind farm as standalone wind turbine capacity has increased. Large-scale centralised wind farms, on the other hand, have introduced additional technological difficulties to the electricity system. Under a fault condition, the short circuit level increase and fault ride-through (FRT) are two major issues. On the one hand, when short-circuit faults occur in power systems, the short-circuit current is supplied not only by the power system source, but also by large wind farm wind turbines, potentially increasing the power system's short-circuit capability, and thus the short-circuit current may not be effectively blocked by existing equipment alone. The fall in generator voltage generated by the system short-circuit defect, on the other hand, causes a sequence of transient events that will cause significant damage to the wind turbines. Due to their excellent energy efficiency, flexible speed, and low mechanical stress, the doubly fed induction generator has become the most popular wind turbine [2]. DFIG, on the other hand, is extremely sensitive to power grid disturbances, particularly grid failures.

Faults can create voltage dips at the connection point, resulting in a significant increase in the power converter's DC link voltage. A crowbar mechanism was used to block the rotor side converter in order to prevent damage to the converter (RSC). The DFIG, on the other hand, loses its ability to manage both active and reactive power while the crowbar



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circuit is operational, and even absorbs reactive power from the system to prevent voltage recovery once the fault is eliminated. In addition, a static series compensator (SSC), or STATCOM, was proposed as a hardware improvement to increase DFIG FRT capacity. This procedure, however, is usually more expensive and has limited usefulness in the event of a significant malfunction.

#### **II. PROBLEM STATEMENT**

Wind energy, like all energy sources, has the potential to harm the environment by reducing, fragmenting, or degrading habitat for wildlife, fish, and plants. Additionally, rotating turbine blades might endanger flying fauna such as birds and bats.

#### **III. LITERATURE SURVEY**

JOHN H. ABEL1, LUKAS A. WIDMER2," A Coupled Stochastic Model Explains Differences in Cry Knockout Behavior" [1] In the mammalian suprachiasmatic nucleus (SCN), a population of noisy cell-autonomous oscillators synchronises to generate robust circadian rhythms at the organism level. Cry1 and Cry2, two Cryptochrome isoforms, are involved in a negative feedback loop that causes oscillation within these cells. Previous research has shown that Cry1 and Cry2 knockouts had distinct effects on single, disconnected SCN neurons. Because of these differences, it has been proposed that CRY1 and CRY2 may serve distinct functions in the oscillator. To investigate this notion, we developed a new coupled stochastic model that focuses on the Period (Per) and Cry feedback loops, as well as intercellular coupling via vasoactive intestinal peptide. We show that single dissociated Cry1 knockouts have a rhythmic pattern. Furthermore, rather than differing roles, intrinsic molecular noise and differences in relative abundance can explain the variety of rhythmicity observed in Cry knockouts in the SCN. The findings highlight the significance of stochastic behaviour in completely understanding and modelling the circadian network.

Khaled. Benyahia1, Larbi. Boumediene1, Abdelkader. Mezouar, "Dynamic performance enhancement of doubly fed induction generator-based wind farm using photovoltaic solar farm as STATCOM" [2] This research looks at how a new control of a photovoltaic solar farm converter (PVSFC) can improve the performance of a doubly fed induction generator wind farm (DFIG) by acting as a static synchronous compensator (STATCOM). The main problem in grid-tied wind turbines is low voltage ride through (LVRT), which is also highlighted. The simulation results suggest that the proposed control can improve the DFIG wind farm's efficiency as well as its LVRT capability. Furthermore, this novel control is less expensive than the traditional devices used to correct for reactive power, such as the STATCOM. This novel concept improves system performance and stability, perhaps paving the way for future wind farm integration.

Yuan Jiaxin, Huang Zehua, Wei Liangliang, Xue Gang, "Fault Ride-through Capacity Enhancement of Doubly Fed Induction Generator Based Wind Farm by Saturated Core Fault Current Limiter",[3] The main difficulties of a doubly fed induction generator (DFIG) based wind farm are increasing short-circuit fault capacity and fault ride-through (FRT). This research proposes a new way for improving FRT capability of DFIG-based wind farms by using saturated core fault current limiters (SCFCL). During a grid fault, SCFCL not only restricts the fault current but also helps to keep the generator terminal voltage stable and reduce the peak value of DC-link overvoltage. By modelling a sample power system in MATLAB/Simulink software, the suggested method's accuracy and capabilities are verified. Furthermore, different SCFCL impedance values and installation locations are examined in terms of enhancement.

Hossein Ali Mohammadpour Enrico Santi, "Analysis of Sub-synchronous Resonance (SSR) in Doubly-fed Induction Generator (DFIG)-Based Wind Farms", [4] In today's energy generation business, wind power penetration is steadily expanding. Due to its cost advantage over fully rated converter-based systems, the doubly-fed induction generator (DFIG) has become a very popular option in wind farms. Wind farms are usually located in rural locations far from the majority of electric power customers, necessitating the installation of long transmission lines to connect to the grid. Series capacitive compensation of DFIG-based wind farms is a cost-effective approach to boost the transmission line connecting the wind farm to the grid's power transfer capability. According to an ABB research, using series compensation to increase the power transfer capabilities of an existing transmission line from 1300 MW to 2000 MW is 90% less expensive than building a new transmission line. However, the likelihood of sub-synchronous resonance is a stumbling block to widespread application of series capacitive compensation (SSR). The frequency of the exchanged energy is below the fundamental frequency of the system, and the wind farm exchanges energy with the electric network



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to which it is connected at one or more natural frequencies of the electric or mechanical part of the combined system, comprising the wind farm and the network. If not addressed, this oscillating behaviour could cause significant harm to the wind farm.

T.A. Taj, 1 Hany M. Hasanien, 1 A.I. Alolah, S.M. Muyeen "Dynamic Performance Enhancement of a GridConnected Wind Farm Using Doubly Fed Induction Machine-Based Flywheel Energy Storage System", [5] This study describes the use of a doubly-fed induction machine (DFIM)-based flywheel energy storage device to improve the dynamic performance of a wind farm connected to an IEEE-39 bus New England test system (FESS). The wind farms' output power fluctuates due to the fluctuating wind speed. The usage of FESS smooths the wind farm's electricity and improves the system's dynamic response during changing wind speeds. This study proposes a DFIM-based FESS that uses an effective control mechanism. The FESS uses a proportional-integral (PI) control method based on a cascaded black-box optimization technique. The insulated gate bipolar transistor (IGBT) based rotor side converter (RSC) and grid side converter (GSC) of the DFIM are controlled by the PI controllers. The PI controller is a device that allows you to control your computer The system under study's modelling and control technique are explained in detail. The suggested system's effectiveness is evaluated using real-time wind speed data. The simulation results obtained with PSCAD/EMTDC are used to verify the system's correctness.

#### V. SYSTEM ANALYSIS



Fig. System Architecture

#### V. EXPLAINATION

Wound rotor induction generators are used in DFIG wind turbines, with the rotor winding fed through a back-to-back variable frequency and amplitude PWM converter. At any practical wind speed, the variable frequency rotor voltage allows the rotor speed to be adjusted to match the optimum operating point [8, 9]. Only rotor power is handled by the variable frequency converter, which is made up of a rotor side converter (RSC) and a grid side converter (GSC). As a result, the machine can be controlled using a converter with a power rating of around 25% -30% of the turbine's rated power [7, 9]. The DFIG's converter is less expensive and smaller than that of variable speed turbines that use a full power converter connected to the stator [7]. The RSC's primary goal is to regulate the DFIG stator's active power, speed, and reactive power. The GSC, on the other hand, keeps the DC link voltage constant [10]. As shown in Fig. 1, the novel nine-switch converters have recently been reported as a competitive alternative to existing PWM back-to-back converters in [11], [12], and [13]. 2. The proposed converter uses only nine power electronic switches, compared to twelve in a PWM back-to-back converter, lowering manufacturing costs and increasing system efficiency. DFIG.

The following assumptions are used to create a generalised machine mode in a DFIG synchronous frame reference.

• For the stator and rotor currents, positive direction is assumed into the generator, and for the grid filter current, positive direction is assumed out of the grid-side converter.



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• All system variables and parameters are stored in per unit and addressed to the stator side.

• During the electrical transients, the rotor's rotation speed is supposed to remain constant.



Figure 2. Nine-switch ac/ac converter.



Figure 3. Proposed DFIG with nine-switch ac/ac converter.

As shown in Fig. 3, this research offers a DFIG with a new nine-switch converter. The following is a breakdown of the paper's structure. The carrier-based PWM switching algorithm for the nine-switch inverter is described in Section II. Section III explains how the DFIG is controlled in a coordinated manner. Section IV presents simulation findings for a 2MW DFIG system based on a novel ac/ac converter, and section V makes conclusions.

A. *NINE-SWITCH CONVERTER:-* The suggested converter consists of three legs, each with three switches. Because the rectifier and inverter share the centre switch in each phase leg, the number of switches is reduced. This setup can also be utilised as an ac/dc converter [11]. The converter input and output voltages can be regulated independently in this configuration, despite the fact that the rectifier and inverter share the centre switch in each leg. The switching states are listed in Table I. This converter has only three valid switching states per phase, as indicated in Table I, where VAR, VXR are the voltages at nodes A and X with respect to the negative dc link R.



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Mode	ON Switches	Input and output nodes voltage
1	SAO, SAM	VAR=Vdc, VXR=Vdc
2	SAM, SAI	$V_{AR}=0, V_{XR}=0$
3	SAO, SAI	VAR=Vdc, VXR=0

#### TABLE I. SWITCHES STATES AND CONVERTER OUTPUT VOLTAGES

For the purposes of this discussion, the input nodes of the converter are x, y, and z, and the output nodes are A, B, and C. The carrier-based PWM control method for a nine-switch converter is depicted in Fig. 4, and the switching strategy is the modulation waveform to switching [11][13]. For each phase, there are two reference signals. The idea of the switching algorithm for upper and lower switches can be described as conditions, e.g., Condition 1: Se1>C then SAO is on Condition 2: Se2C then SAI is on Se1and Se2 can be expressed as:

$$Se1 = mout \sin(2 * \pi * fout) + ofout_{(1)}$$
$$Se2 = m \sin(2 * \pi * f) + f_{in} \qquad (2)$$

Where fot and fin are the output and input frequencies, mout and min are the modulation indexes, and ofout and ofin are the offsets of the output and input reference signals, respectively. The logical NAND of gate signals for the upper and lower switches generates the mid switch.

In the new DFIG architecture, x,y, and z are connected to the grid, and lower switches (SAI, SBI, SCI) work as a rectifier or GSC, while A, B, and C are connected to the rotor, and upper switches (SAO, SBO, SCO) operate as an inverter or RSC.



Figure 4. Modulation waveform to nine-switch converter.



Figure 5. Mid switches gate signal generator circuit

#### VI. THE WIND FARM SSR PHENOMENON DESCRIPTION

#### B. Wind Power System Description

The I and II wind farms are connected to 1 # 500kV substation by a 210Mvar transformer, and then to 2 # substation via a transmission line access, which is a regional power grid access. Between 1 # and 2 # substations, a 500kV single back line is installed. The wire type is LGJ-6 h 300/40, with a 6.7m line gap between phases and a 203km line length. On the



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2 # substation side, a fixed series compensation equipment of 40% is placed. The wind power transmission capacity is 2300MW, whereas the short-circuit current in 2 # substation is 50kA.

#### C. SSR Phenomenon Description

The 7Hz harmonic content of the wind power transmission system in the 220KV line is extremely high during the Sub-Synchronous Resonance (SSR) phase. The present oscillation appears when the subharmonic content exceeds roughly 3%. During synchronous oscillation, the voltage and current waveforms of the 35kV line show substantial variances. The current will be divergent when the voltage is more than 2% to 3% higher. Because of the flaw, the wind turbine will stop spinning if the voltage exceeds 4%. In 690V line voltage, there was a 5-9Hz sub-harmonic. Current oscillation causes wind turbines to be removed from the grid when the harmonic RMS is larger than 25V 30V.

#### VII. CONCLUSION

The DFIG suggested in this research uses a new nine-switch ac/ac converter. There are fewer switches and gate driving circuits in the proposed design. As a result of the proposed topology, the installation area and cost are reduced. For the innovative converter, a PWM-based switching technique is also described. In addition, a DFIG control method based on a recommended converter was described. The simulation results suggest that the proposed DFIG can operate in the wind speed rapid variations according to control schemes. Wind power's growing penetration into electric power systems around the world necessitates power companies' ability to transmit generated wind power without congestion. Furthermore, given the global trend toward deregulation of the power market, any solution to expand the power transfer capability of an existing transmission line must be economically viable. In many circumstances, cost-effective series compensation enhances the transmission line. However, one obstacle preventing widespread usage of series capacitive compensation is the potential risk of sub-synchronous resonance (SSR), which, if not avoided, might cause significant damage to the wind farm.

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