Overview of DFIG and PMSM for the Voltage Fluctuations in Wind Turbine System

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Abstract: *Concerns about rising electricity demand, the gradual depletion of fossil fuels, reduced carbon emissions, improved infrastructure reliability, and other factors have prompted power utility companies to incorporate renewable energy sources into traditional power systems. Penetration level of non-dispatchable renewable energy sources such as solar photovoltaic (PV) and wind energy into emerging distribution and transmission networks has resulted in a number of system voltage stability concerns***.** *This paper present an overview of DFIG and PMSM for the voltage fluctuations in wind turbine system foe electricity generation transmission.*

Keywords: Power system, DFIG, PMSM.

I. INTRODUCTION

A marketable electricity power system is built on a deregulated market framework that contains electricity provider as well as consumer transactions, coordination, as well as rules that ensure competition and non - discriminatory open access. The goal of deregulation is to substantially decrease the price of power charged to consumers while also ensuring the practicability of the generating company in terms of generating revenue without jeopardising grid safety and stability [1]. An energy trading system facilitates this restructured power system goal, that also involves ability to compete and consumer preference. Infrequent production is a feature of green power. To ensure grid reliability for consumers and maximise revenue for generators, production and load predicting, models for market strategy optimization, and recognition of uncertainties are required for green power trade to be rigorous. Wind resource analysis is an essential tool for wind turbine configuration, wind farm design, and operations and maintenance wind farm load forecasting. This is a predicting problem, and analytical modelling is used to solve it.

Wind energy is gaining importance in global energy markets, and because it has been promoted as a clean and limitless energy source, its global penetration has enhanced. However, due to the unpredictable nature of wind, altering wind power occurs, causing network destabilisation as well as other issues such as voltage regulation, reactive power, fluctuation, harmonics, and flickering. [2].With the increased use of wind generation, a wind farm must be capable of providing network services and procedure in the same way that a traditional power generating system does.
The active power supply is primarily determined by the wind turbine generator configuration and the possibilities of the wind energy generated. Reactive power demand, on the other side, is determined by conversion devices and the quality of retrieved power fed to the grid. Wind farms that connect to the power grid cause voltage instability, reactive power redistribution, and voltage collapse. Distribution network operators face a number of challenges, including voltage fluctuations due to variable wind generation as well as dynamic voltage consistency.

Since all wind farm technology is not created equal, reactive power control is essential. Because wind farms are typically built in remote locations, reactive power must be transported over lengthy ranges, tends to result in power loss. In reaction to voltage variations, the wind farm must provide reactive power control [4– 6]. Since this influence of reactive power injection at various voltage levels is dependent on network short circuit capacity and impedance, the reactive power control necessity is linked to grid characteristics. Uncompensated reactive power causes stress on the hosting grid as well as casting effects, so reactive power compensation is becoming a must for wind farm procedure and ability to contribute to the power grid. In overall, the purpose of reactive power compensation for wind farms is to maintain a wind farm's voltage profile at an appropriate level and ensure minimal losses when transmitting power to the main grid, as well as to comply with grid code's connection requirements for reactive power exchange.

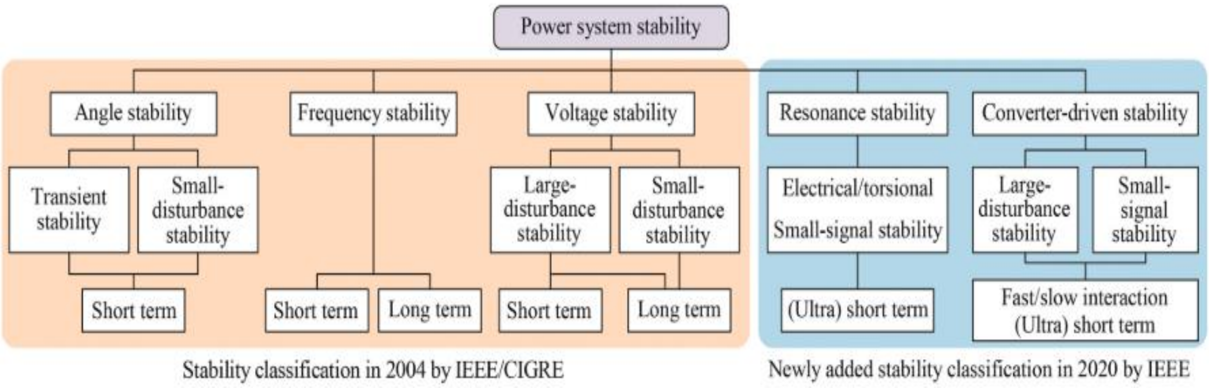

Figure 1 Stability classification of modern power systems with high-penetration power electronics

Numerous synchronous generators are linked to a bus with the same frequency and phase sequential manner as the generators in power plants. As a result, for a stable operation, we must synchronise the bus with the generators throughout the entire generation and distribution process. As a result, power system stability is also known as synchronous stability, and it is defined as the ability of the system to return to synchronism after being disrupted by switching on and off of loads or by line transience. Some other aspect to consider in order to fully comprehend stability is the system's stabilisation limit. The stability limit specifies the maximum possible power that can flow throughout a component of the system that is subject to line disturbances or faulty power flow.

The power system stability, or synchronous stability, of a power system can be divided into various types guess it depends on the nature of the disruption, and it can be categorised into the three types shown below for successful analysis:

- Stability in a steady state;
- Stability in a transient state;
- Stability in a dynamic state.

Steady State Stability of a Power System

A power system's steady-state stability is interpreted as the capability of the system to return to its stable configuration having followed a minor network disturbance (like normal load fluctuation or action of automatic voltage regulator). Only during a very progressive and vanishingly small power change can it be regarded.

If the power flowing through the circuit reached the threshold permissible, a single machine or a group of machines may cease to continue operating in synchronism, causing even more disruptions. In this case, the system's steady-state limit, or steady-state stability limit, was shown to be reached. The steady-state stability limit of a system refers to the total amount of power that can be transmitted through all the system without compromising its steady-state stability.

Transient Stability of a Power System

The capabilities of a power system to return to a stable state after a large disturbance in the network condition is referred to as transient stability. The transient performance of the system comes into effect in all cases involving large changes in the system, such as sudden implementation or removal of the load, switching operations, line faults, or loss due to excitation. It is actually concerned with the system's ability to maintain synchronism following a disturbance that lasts for a reasonable amount of time. The maximum power that can flow through the network without causing a loss of stability after a consistent period of disturbance is made reference to as the system's transient stability. The system would become temporarily unsteady if the allowable maximum value for power stream was exceeded.

Dynamic Stability of a Power System

The artificial stability provided to an inherently unstable system by automatic control means is referred to as dynamic stabilisation of a system. It is concerned with minor disruptions lasting 10 to 30 seconds.

Variable Speed Wind Turbine

Turbine blades, rotor, generator, nacelle (gearbox and generator drive), shaft, drive or coupling device, converter, as well as control system make up a wind turbine (WT). Fixed-speed wind turbines and variable-speed wind turbines are two types of wind turbines. The constant speed turbine can only perform at a fixed speed, and the generator is an induction machine. A generator in a variable speed wind turbine is either a double fed induction machine (DFIG) or a permanent magnet synchronous machine (PMSM). In summary, the mechanical drive and control, generator, converter, and control system are the three main components of a wind turbine model. The generator's model is highly essential.

DFIG - A wound rotor asynchronous generator with stator windings straightforwardly grid connected and rotor windings linked up with a back-to-back variable frequency VSC makes up the DFIG model. This unit allows for variable speed operation across a broad range of speeds, from sub-synchronous to super-synchronous. The basic arrangement of a DFIG wind turbine is shown in Figure 2. On the rotor side, a back-to-back power converter allows the control action on the DFIG to be decoupled.

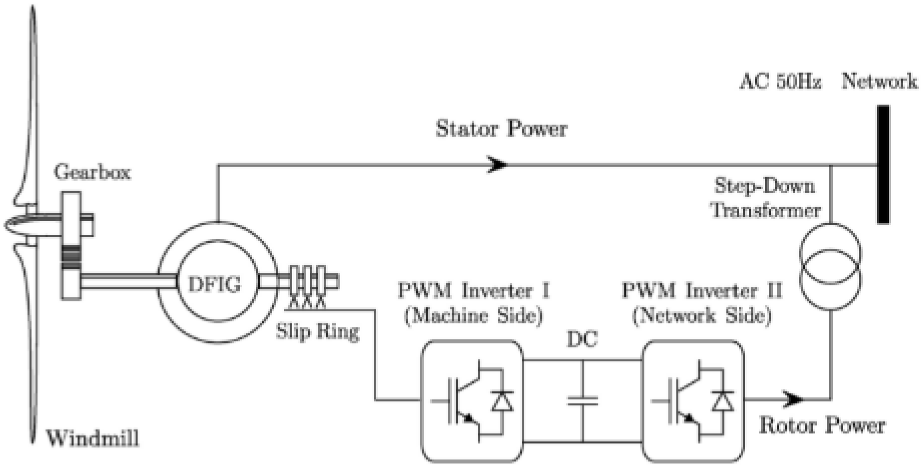

Figure 2 CONFIGURATION OF A DFIG WIND TURB INE

The rotor side converter is being used to enhance the DFIG's power generation and stability, whereas the grid side converter makes sure a fairly constant voltage on the DC link with a preferred power factor. Four quadrant PWM AC/DC and DC/AC inverters are used to model the grid and rotor sides of the converter. The power flow here among rotor circuit as well as the replenish can be controlled both in direction and magnitude by adjusting the switching of the Insulated Gate Bipolar Transistors IGBT) in both converters. This is the same as connecting a rotor circuit to a manageable voltage source. The DFIG is an induction generator with a nonzero rotor voltage, similar to a conventional induction generator.

PMSM - The permanent magnet synchronous motors are very efficient, brushless, very fast, safe, and give high dynamic performance when compared to the conventional motors. It produces smooth torque, low noise and mainly used for high-speed applications like robotics. It is a 3-phase AC synchronous motor that runs at synchronous speed with the applied AC source. Instead of using winding for the rotor, permanent magnets are mounted to create a rotating magnetic field. As there is no supply of DC source, these types of motors are very simple and less cost. It contains a stator with 3 windings installed on it and a rotor with a permanent magnet mounted to create field poles. The 3-phase input ac supply is given to the stator to start working.

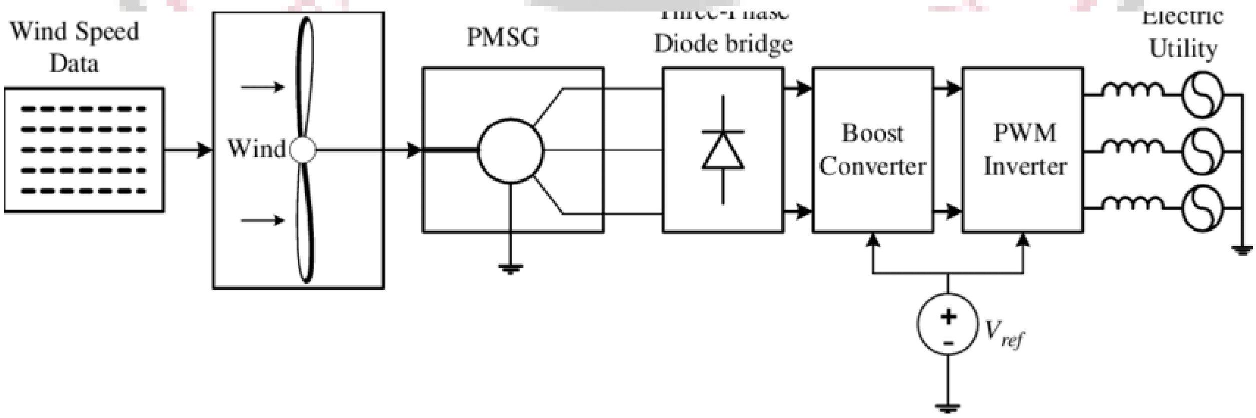

Figure 3 Configuration of PMSM Wind Turbine

The permanent magnet synchronous motor working principle is similar to the synchronous motor. It depends on the rotating magnetic field that generates electromotive force at synchronous speed. When the stator winding is energized by giving the 3-phase supply, a rotating magnetic field is created in between the air gaps. This produces the torque when the rotor field poles hold the rotating magnetic field at synchronous speed and the rotor rotates continuously. As these motors are not self-starting motors, it is necessary to provide a variable frequency power supply.

II. LITERATURE REVIEW

(Chinmoy et al., 2019)reviews the various aspects of modelling wind energy systems for integration in deregulated markets, including investment, policies, performance, and state welfare. Models for wind energy systems are based on wind resource, electrical response of wind turbine generators, and economic stock return. The paper aims at identifying sub-problems and modelling approaches for each of them. The local power system's and wind resource's variability is chaotic and complicated to model. Algorithms that are adequate and some that are successful are discussed in details.
(Parameswari, 2020)The study presents an insight into various strategies used to improve the fault Ride-Through (FRT) ability of DFIGs-based Wind Turbines (WTs) during transient states. In the literature, numerous FRT strategies based on (a) the installation of additional safeguard circuits, (b) the installation of reactive power injecting devices, and (c) various control measures have been developed.

(Pathak et al., 2015)Distribution network operators face a significant challenge in maintaining dynamic voltage stability. Installing reactive power source devices and optimising existing assets to deliver enhanced reactive power to the grid is a simple solution. With solutions for reliability, voltage regulation, reactive power prerequisites, grid integration issues, weak grid connectivity, off-grid wind power generation and grid integration, wind power penetration in distribution grid, wind power uncertainty, flicker and harmonics, and other issues. The objective of the project is to maintain reactive power of wind farms in the most technological and cost-effective way possible without compromising quality power system voltage, while taking into account wind turbine technology for already-commissioned wind farms and changes in WT technology in the current scenario.

(Dineva et al., 2019)focuses on the state in soft computing techniques applied, which have had a significant impact on the development of this important field of energy. The most important breakthroughs in the field are evaluated using a novel taxonomy of systems and applications to provide insight into the development of rotating electrical machine control as well as design.

(Saha & Singh, 2019)explains a few concepts and strategies for detecting and controlling faults in wind turbines, which are a major source of renewable energy. Because of the desired levels of accessibility, efficiency, and reliability of the source, i.e., wind, wind turbines are becoming increasingly popular. Diagnose and advanced health monitoring, as well as fault-tolerant control (FTC) and optimal control, are some of the key technologies used to ensure the reliability and efficiency of modern wind turbines.

(Tal et al., n.d.)present the performance of various LVRT capability enhancement methods, as well as the application of some LVRT functionality methodologies in PMSG-based wind turbines and other types of wind power generators. External device-based methods can be efficient, but some of them are extremely expensive. Modified controller-based methods, according to the literature, can lower the cost of LVRT performance enhancement. Several modified controller-based methods for improving LVRT capability have been suggested. Some many simulations in MATLAB software are used to compare the techniques outlined. The highly efficient LVRT capability enhancement approaches, as per simulation results, are linked to a series of FACTS devices and modification of back-to-back converter controllers.

(Rawat & Vadhera, 2019)presents critical aspects such as optimum locations and sizing of distributed generation (DG) units based on voltage stability, voltage stability assessment, and improvement techniques. The effect of power system devices like fixed capacitors, flexible AC transmission systems (FACTS), and energy storage systems (ESS) on transmission & distribution network voltage stability is also explored. The review's outcomes therefore provide good overview for investigating voltage stability in non-dispatchable renewable integrated power systems, as well as major outcomes and observations of prospective power system stability studies.

(Wang & Wang, 2021)A thorough examination of STATCOM control techniques based on traditional, adaptive, nonlinear, predictive, robust, and coordinated control as well as soft computing methodologies is offered. In addition, the grid-side converter of the wind/PV plant's function as a STATCOM is assessed. Finally, the limitations of previous research are spotlighted, current control challenges are displayed, and several research topics are suggested for additional investigation.

(*Impact of Renewable Generation on Voltage Control in Distribution Systems*, n.d.)Voltage difference; degraded safeguards; modified transient stability; two-way power flow; and enhanced fault level have all been introduced by the high penetration of renewable generation in the distribution system (DS). Due to the high permeation of renewable generation, reverse power flow may cause voltage rises that distribution network operators (DNOs) may not be capable to control. To that end, this paper examines the impact of renewable energy sources such as solar photovoltaic (PV) and wind energy on the distribution system, as well as voltage control strategies. The findings show that smart grid technologies like demand side integration (DSI) and energy storage (ES) can reduce voltage variation while requiring minimal network reinforcement.

(He et al., 2021)provide a thorough overview of wind turbine generator modelling for a variety of stability studies A broad categorization of models are discussed to distinguish the modelling needs in various stability studies, taking into account aspects such as time scale, perturbation size, stability study methodology, and modelling research methods. To confront how to custom-tailor an appropriate model for specific types of stability studies, a conceptual modelling framework is established. Furthermore, the accomplishments in various aspects of modelling are thoroughly examined.

(Okakwu et al., 2017)Among several investigators of Power Systems stability studies, intelligent-based optimization techniques have become an essential approach for resolving various Power Systems stability issues. Improvement of Power System Transient Stability in Settling Power System Stability Issues is the subject of this paper. The purpose of this literature review is to provide references for educational advancement on newly reported journals in the field of power system stability, as well as to pique attention in further research.

(Singh & Sharma, 2017)presents a comprehensive review of distributed generation planning in distribution power system networks from various power system showings such as minimising real and reactive power loss, increasing power system throughput, increasing power system stability, increasing power system reliability, increasing power system reliability, increasing available energy transmission rate, and reducing power system oscillations.

(On et al., 2013)The problem of wind power's impact on power system stability has piqued researchers' interest as its penetration level rises in the power system. This paper examines numerous generator models for power system stability studies, as well as the effects and improvement of power system stability in grid-connected wind power systems.

(Mwaniki et al., 2017)presents a brief overview of the DFIGWECS, including its design, operation, advantages, disadvantages, modelling, control types, levels, and strategies, faults and possible solutions, and simulation. After that, qualities for the best control strategy are proposed. The purpose of this paper is to cover major issues related to the DFIG WECS that are required for a comprehensive understanding of the system, and thus serve as an introduction for newcomers to this field of study.

(Dev & Tripathi, 2014)introduces a unique speed-sensorless control scheme for a doubly-fed induction generator supplying energy to an isolated load in a stand-alone configuration. The detection scheme is based on the root mean square (rms). Rotor currents regulate the generated stator voltage. The frequency and amplitude of the stator voltage are both controlled at the same time. The voltage controllers' output signals serve as reference signals for the rotor current amplitude, and the frequency of the stator voltage is controlled by a frequency control loop.

III. CONCLUSION

In this paper, an overview of different modeling techniques of wind energy conversion systems is provided, as well as an assessment of small signal and transient stability and stability enhancement. Numerous wind energy conversion system models for stability studies have been proposed by researchers and reported in the literature review.

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