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GRID IMPACTS ON WIND ENERGY

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***Abstract*— Increased system uncertainty brought on by a growing grid penetration of renewable energy sources like wind power generation may significantly reduce the grid's sensitivity to cascading failures. In this study, we present a mixed stochastic approach for cascading grid failure analysis and simulation as well as evaluation of the penetration and uncertainty of wind generation. Unpredictable generation, power quality issues, angular and voltage stability, reactive power support, and fault ride-through capability are a few of the difficulties that must be overcome. The difficulties the electrical market faces as a result of the grid integration of wind power are examined along with these other factors. Several solutions have been developed and implemented in order to lessen the effects of these difficulties.**

INTRODUCTION:

Worldwide, the use of wind energy is expanding at a rapid rate, and in the majority of the countries that have made sizable investments in this field, it currently plays a critical role in grid maintenance. Every year, the amount of wind power generated globally contributes more to the world's energy supply and is integrated into the electrical grid. It is necessary to keep up with this ongoing increase and penetration of tools and information that assist operators in controlling the grid with dependability and resilience. The operators are concerned about a number of concerns, including power prediction, voltage/reactive power support, frequency stability, harmonics, power quality issues, small-signal stability, low voltage ride-through capabilities, protection, the electricity market, and other challenges. The majority of the important grid challenges are examined [1].

Power grid operation characteristics during grid disruptions may evolve as installed wind power capacity in the grid increases and the related interaction between wind turbines and the power grid decreases, primarily in weak networks. Large-scale doubly fed induction generator (DFIG)-based windmills with limited grid connectivity may experience difficulty with dynamic stability. Finally, the simulation results are used to examine the impact of power outages and short circuits on the stability of a large-scale DFIG-based wind turbine information model.

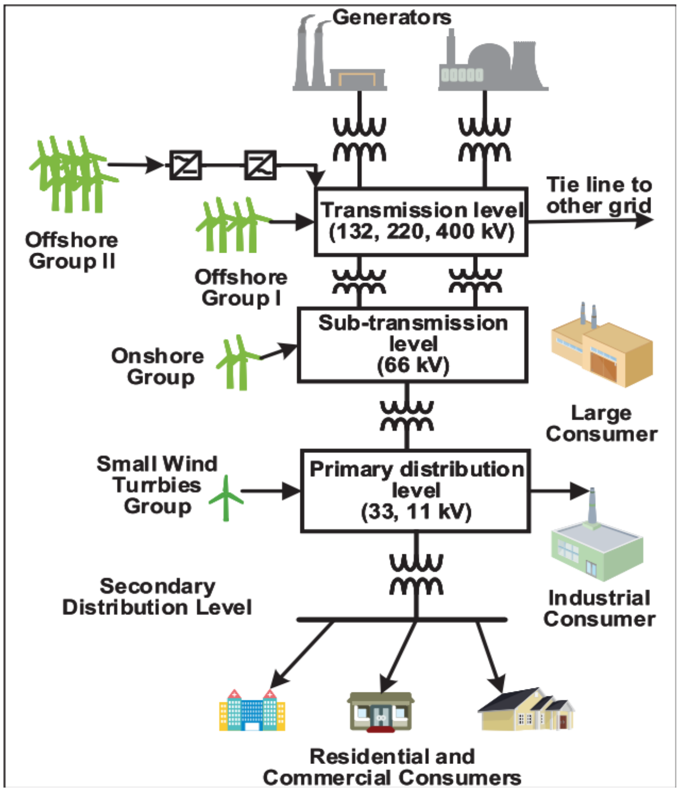

Fig: Grid with wind system integration [1].

CHALLENGES OF WIND ENERGY INTEGRATION:

Wind, as a clean and environmentally friendly energy source, makes an important contribution to modern electric systems. The unique characteristics of wind energy systems, such as intermittent power, turbine technology, and protection issues, create additional barriers to efficient and cost-effective grid integration. This section examines the network implications of wind energy integration, which must be taken into account in order to maintain the stability and quality of power delivered to customers.[1].

TIME-FREQUENCY ANALYSIS TECHNIQUE FOR WIND POWER GRID CODES:

Wind power plants (WPP) provide intermittent electricity. As a result, the application of time-frequency analysis (TFA) in wind energy is justified since it overcomes the limitations of the traditional fast fourier transform (FFT) approach in non-stationary data settings. Reduced interference distribution (RIDB) is a technique for testing wind power grid codes in imbalanced and distorted grid environments. Because the signal appears twice in the Time frequency distribution definition, TFA is a bilinear transform (TFD). As a result, unnecessary data must be removed in order for the suggested TFA technique to process less data at the supervisory control and data acquisition (SCADA) center. Precision data for the SCADA system is obtained by identifying critical nodes for possible voltage breakdown [2].

MODELING OF DFIG-BASED WIND TURBINES:

Wind turbines help to regulate frequency by releasing energy stored in their rotors using a virtual inertia control technique. The rotor speed variation is unavoidable; thus, the wind turbine machine should be evaluated alongside the converter. This paper models a two-mass generator—turbine system to characterize the dynamic properties of the machine part. The most power point tracking (MPPT) mode is frequently utilized to obtain the greatest output from a wind turbine [3].

Control Strategy of Grid Frequency on wind system:

Under warped and twisted grid voltage, the phase locked loop (PLL)-derived grid frequency must pass through a low-pass classifier with a low cut-off frequency. The delay introduced by the low-pass filter is incompatible with the purpose of providing quick assistance for virtual inertia control. The virtual inertia control technique rapidly increases turbine electromagnetic torque, aggravates transmission shafting twisted vibration, and generates low-frequency oscillation in wind farms.

Wind turbines contribute to frequency regulation by releasing energy stored in their rotors using a virtual inertia control approach. The fluctuation in rotor speed is impossible to ignore, therefore the wind turbine machine should be considered alongside the converter. The enhanced control approach has almost the same ability to reduce time delay and has a greater range of parameters before the system reaches the unstable area [3].

SYSTEM ANALYSIS AND IMPROVEMENT:

To minimize fluctuations in system frequency, DFIG-based wind turbines employ virtual inertia control to vary output power. The virtual inertia control parameter affects the capacity of the wind turbine to sustain grid frequency. Because the focus of this study is not on the inertial control settings, will remain constant in the following analysis. The phase secured loop (PLL) system's frequency is frequently accompanied by a number of high-frequency components caused by grid voltage harmonics. To filter the high-frequency components, a low-pass filter is required. When a wind turbine actively supports grid frequency under virtual inertia management, its reaction process and control characteristics are influenced not only by inherent features, but also by the wind turbine's operational state [4].

OVERVIEW OF THE SYSTEM AND ANALYSIS OF WIND TURBINE CHARACTERISTICS:

The figure displays a high-level overview of the proposed DC grid-connected low-power wind energy conversion system (WECS) system and its control mechanism. It is split into two parts: the wind turbine system and the voltage conversion system. Wind energy is converted into alternating current (AC) electrical energy via the wind turbine system.

The voltage conversion system converts alternating current electrical voltage to direct current grid voltage and injects power into the grid.

Maximum power generation (MPG) can be achieved by controlling the torque of the wind turbine using the maximum power point tracking (MPPT) system. However, it should be noted that in the absence of local storage, all generated power must be pushed into the grid. Power production will be halted if this is not done.

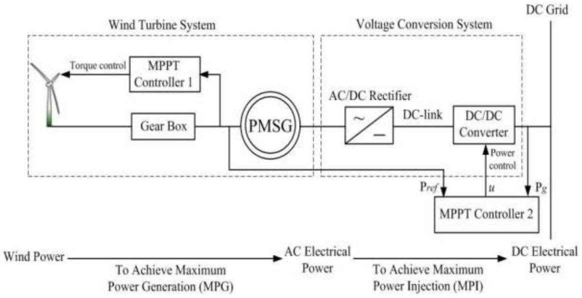

Fig: Low Power-WECS system [4].

Grid Reactance Changes Weak Grid Double Mode Control Technique:

As distributed energy resources become more common and access points become more widely distributed, the power grid is becoming highly subject. The inverter operates at CSM when the grid amplitude is low, and at VSM when the grid impedance is high. Finally, the previous simulation and experiment are used to validate the analysis and the effectiveness of the proposed scheme.

Because of the widespread distribution of access points, the power grid is becoming highly subject. This paper examines the rigid characteristics of power transmission for the two main weak grid stability control strategies, namely the current source synchronous generators mode (CSM) and the voltage source grid connected mode (VSM). Furthermore, when the grid impedance increases, the stability and dynamic performance of the inverter operating at VSM are improved through small signal modelling and analysis. Furthermore, the inverter is found to be better suited for VSM operation in higher grid impedance situations [5].

Power grid connection dynamic stability mechanism of large-scale DFIG-based wind turbines:

The doubly fed induction generator (DFIG) has a quick control response, leading to a significant dynamic interaction between the DFIG and numerous different uncertainty operation considerations. For starters, in the presence of an active or reactive power disturbance, increased voltage sensitivity may cause power oscillation. Second, removing the fault line weakens the power grid, increasing the likelihood of power oscillation. According to the study, the induced voltages and currents of the stator are caused by the grid disturbance; the superposed outcomes of the induced voltages and currents of the stator and the original grid disturbance may cause the wind power actual model to become unbalanced.

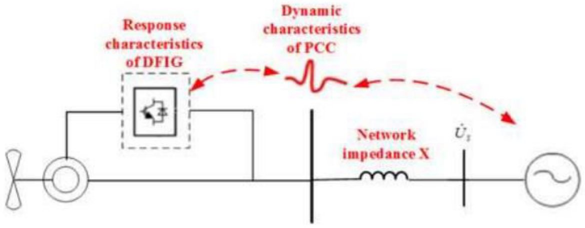

Fig: Weak grid connection of large-scale DFIG-based wind turbines [6].

The controllability issues associated with a large-scale DFIG-based wind turbine integration system are reviewed. The analysis of wind farm voltage sensitivity and the reaction process of a control system of a DFIG-based wind turbine to progressive electrical parameters of the system may provide the instability modes. It is confirmed how the DFIG-based wind turbine interacts with the wind power integration system. A large-scale DFIG-based wind turbine connection system's oscillation type is described in detail [6].

Control sensitivity of DFIG-based wind turbines:

The control objectives of the DFIG are to complete trading reactive power between the DFIG and the grid in complies with needs, generate active power at the optimal process point, or reduce the wind turbine's outcome load demand at high wind speeds. The DFIG model and tracking solution scheme independently control active and reactive power.

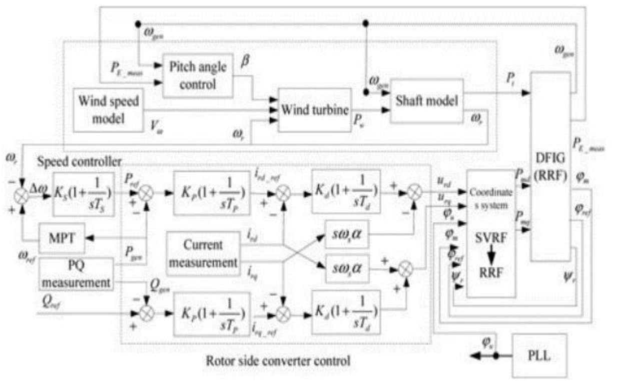

Fig: DFIG model and control scheme [6].

Because DFIG-based wind turbines have a lower rotor converter capacity and the grid-side converter controller can maintain the stability of exchanging power between the rotor and the grid under steady-state operating conditions, the interaction between the rotor and the grid can be ignored. The weak grid connection of large-scale doubly fed induction generator (DFIG)-based wind turbines is used to analyze the dynamic stability of the power grid, where the dynamic characteristics of the power grid are represented by the interaction between the DFIG and power grid, which can be analyzed using the interaction-based sensitivity analysis method, and the interaction is coupled based on the voltage dynamic characteristic at the DFIG's common coupling [6].

Effects of Advanced Forecasting of Wind Energy on Grid Reliability:

Increased wind output predictions are widely recognized in the electrical business to bring significant system improvements. Calculating the value assigned to a certain degree of wind forecast improvement, on the other hand, is challenging. Its because the connection is influenced by a variety of factors, including conventional generation mix, wind penetration level, and forecasting timelines. Besides, a number of other factors may obscure the system's advantages from optimized wind forecasting.

Wind energy forecasting accuracy has increased significantly in recent years as a result of the adoption of new statistical and machine-learning approaches, as well as the introduction of "big data" and other cognitive computing technologies. The research on wind power forecasting has been divided into three categories: methodological breakthroughs, grid implications on a specific topic (such as transmission loss, generating dispatch, energy storage, and branch limits), and economic implications from a whole-system perspective. Researchers in the first category have concentrated on developing novel methods to improve intra-hour, intra-day, or day-ahead (DA) wind predictions, such as the integrated Gaussian process and numerical weather prediction (NWP), sparse vector auto regression, and ridge let neural network methods. Wind forecasting systems have also been developed by researchers [7].

Overview of FESTIV:

FESTIV normally carried scheduling sub models with varying time resolutions while taking their inter-temporal connection into account. It is analogous to system operations at ISOs, regional transmission organizations, and transmission system operators, and its sub models include DA security-constrained unit commitment (DASCUC), SCED, and AGC. The frequency (typically 2-6 seconds) at which AGC is performed, production costs, MW imbalances, and branch flow violations are all recognized at the finest scheduling interval. These simulations are suitable for examining the time-varying consequences of enhanced wind forecasting. This multi-time resolution integrated modelling technique is critical for gaining a more comprehensive understanding of the effects of variability and uncertainty.

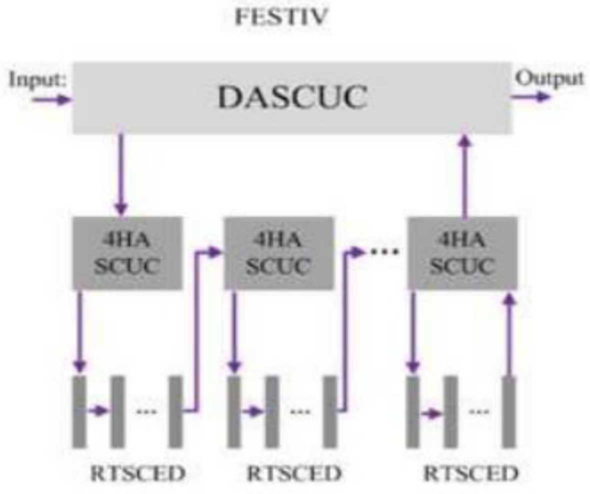

Fig: Model information flow in FESTIV [7].

POWER SYSTEM’S FREQUENY FLUCTUATIONS:

In order to maintain a constant system power frequency, the power source is continually updated to follow the load. Even though load is predicted, there are situations when the prediction and actual load disagree. Moreover, power supply may differ slightly from a sudden loss or surplus of power various faults, errors, or a fluctuating generator. The degree of this shift is dictated by the difference between supply and load, as well as a power system's sensitivity to the time necessary to close the gap. Wind power changes and, depending on its frequency, amplitude, and phase angle, both smoothest and accentuates the gap between load and supply. It also makes the power system more sensitive since it lacks inertial resistance [8].

WIND POWER SYSTEM AND TRADITIONAL LADRC:

The inverter primarily regulates the motor speed or torque to achieve maximum power point tracking of wind energy on the machine side. The grid-side converter is primarily used to control grid-connected power factor and power quality while also maintaining DC bus voltage stability. The linear tracking differentiator (LTD) tracks the input signal, extracts the differential signal, and resolves the conflict between overshoot and rapidity. LTD is not used in this research to avoid high frequency oscillations of the DC bus voltage. Linear extended state observer (LESO) can observe, estimate, and correct for separate state distinct values and oversimplified disturbances of monitored objects, simplifying the system and eliminating the need for a mathematical model.

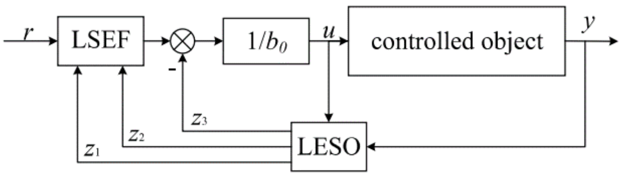

Fig: Typically two LADRC layout [9].

CONTROL OF THE MSC:

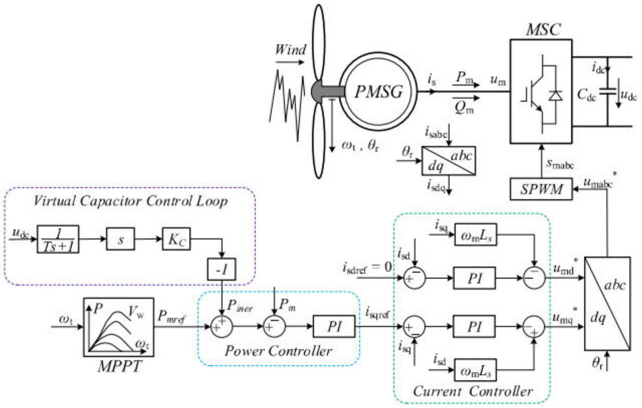

Fig: Control schematic of virtual capacitor control of MSC [10].

The System uses a vector control system based on rotor flux linkage orientation, with a control structure that includes an inner current loop and an outer power loop. Figure depicts the MSC's control scheme. The shaft encoder measures the position angle 6 of the rotor flux linkage, which supplies the phase for the stator current changing from the stationary frame to the rotating d-q frame. Figure shows the maximum power point tracking (MPPT) control by computing the active power reference. Because the magnetic flux linkage of the rotor aligns with the d axis in the rotational d-q frame, when the d-axis current of the stator is zero, the output real power of the permanent magnetic synchronous generator (PMSG) is proportional to the q-axis current [10].

$$P_{mref} = k_{o_{Pt}} w_t^3$$

Frequency stability of power stability on wind energy:

Extra distributed generation will have an effect on the reliability and stability of the power system. Wind power, as a dispersed generator, lacks axial response and control. The impact of frequency variations is discussed, as well as future changes in power supply and load fluctuations. In the event of higher frequency power fluctuations, a method for computing wind power variations in the frequency domain and comparing them to load changes. Wind power smoothing is thought to be a means of reducing the grid impact of power fluctuations. Power stations are used to reduce the grid impact of wind power fluctuations on a power system's frequency stability. A smart grid may include control mechanism to limit the grid effect of wind generation.

IMPACT OF THE FREQUENCY:

Wind-generated power added to the grid helps to reduce overall system inertia, which has a significant impact on smaller isolated systems. In the case of a disruption, most wind power plant control systems separate the mechanical system from the electrical system, reducing the wind power plant's contribution to network inertia. During frequency oscillations, a controller to regulate the output power of a permanent magnet synchronous generator (PMSG) based on grid frequency and another control technique were evaluated on a PMSG wind turbine. During a disturbance, the windmills can try to imitate conventional generators and provide rotational support by of using the wind turbine's invisible kinetic energy [10].

GRID RELIABILITY AND RESILIENCY:

1) Support for frequency by ensuring the balance of generation and demand across the electrical system and responding quickly in times of imbalance by decreasing generation or demand. 2) In regular or emergency operations, keep the voltage within the grid's operational limits in order to keep the system from collapsing. The traditional manufacturing system provides these services as an essential component of its operation, but the arrival of renewable energy sources has changed that, such as wind turbines, has changed the grid's dynamic.

Many processes and approaches in power quality analysis involve optimization algorithms. The integration of renewable energy supplies has resulted in a variety of power quality difficulties, and two control systems to improve power quality have been developed: the Virtual Synchronous Machine (VSM) method and Virtual Impedance Control. Methods for detecting and categorizing power quality in the grid, as well as well as the both hardware and software structures used for monitoring power quality in the presence of renewable energy are described. Power quality, as well as rapid detection and classification technologies, are crucial in detecting disruptions early on [11].

Power Quality issues of Smart Grids:

As the power system network matures, demand grows, and service quality improves, the smart grid concept is advancing to replace the traditional power grid. The majority of equipment in the smart grid environment is sensitive, i.e., intelligent, smart, and sensitive control equipment is employed with distributed generation (DG) and energy efficient devices. The primary functions of smart grids are electronic power conditioning, production and distribution control, improved reliability, security, and efficiency, optimization, and integration of distributed generation (DG), which includes RES, real-time, interactive, automatic, and energy-efficient operation. Smart grids are increasingly popular for meeting demand response needs, energy forecasting, future planning, microgrid applications, power system stability, and DERs integration.

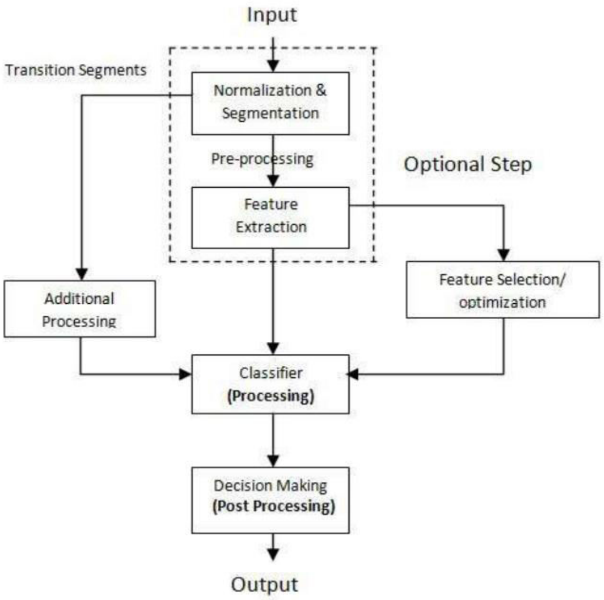

Fig: Power system interference analysis localized block diagram [11].

Issues with System Reliability in Sustainable Energy with Grid:

To lessen the greenhouse gas effect, power system researchers' efforts toward renewable energy supplies have intensified, giving rise to grid integration. Through islanding, transmission based on distributed energy resources (DER) improves efficiency, restricts line losses, and positively impacts dependability while increasing system complexity. As an alternative to smart grid, the author recommends small structures or microgrids of power sources for greater dependability, optimization of renewable resources, islanding, increased efficiency, and distributed control. The interconnection of RES with the network causes several PQ issues in the power system, such as voltage fluctuation, transients, flickers, harmonics, and frequency changes [11].

Tabular form:

S.No	Paper About	Methodology Adopted	Merits	Demerits
1.	Critical analysis of Methodologies for detection and classification of power quality	The integration of renewable energy supplies has resulted in a variety of power quality difficulties, and two control systems to improve power quality have been developed: the Virtual Synchronous Machine (VSM) method and Virtual Impedance Control.	1)Detection of power quality disturbances 2)Feature extraction and pre-processing	1)It has an impact on environmental elements. 2)Problems with smart grid power quality
2.	Grid reliability in Smart Grid on Wind Energy	It will be determined which reliability services provide grid reliability in terms of 1) frequency and 2) voltage techniques.	1)Emergency operation to keep the systems from crashing. 2)The electrical generation mix has affected the grid's dynamics.	1)It may result in noise pollution. 2)Wind turbines pollute the environment visually.
3.	Impacts of Wind Generation Change on Power Grid Angle	In a power system, topology the impacts of different quantities of wind energy generation on the power angles in the switches checked incorporated in the system grow.	1) The worldwide breadth of wind resources is immense. 2) Less depending on latitude	The wind is excessively powerful and shifts with regard to the power angle.
4.	A Different Design at Wind Power Grid Codes in Unstable and Disrupted Grid Conditions	It is developed a new time-frequency analysis technique for grid coding for wind power under imbalance and obscured grid conditions.	1)To solve problems using temporal frequency analysis approach. 2)TFA produces accurate results in both steady-states and transient conditions.	1) WPP can operate at low voltages. 2) A higher power factor and a lower control factor
5.	The Improve of Energy Efficiency on Grid Based Wind Power System	A series-connected current source converter (CSC), an open-end winding configuration, a doubly fed induction generator, and a modular multilevel converter (MMC) were developed and used to improve efficiency.	1) To improve energy stability for grid-connected wind power systems. 2) Increase efficiency and cost-effectiveness	Pressure, humidity, heat, and height are all factors.

S.No	Paper About	Methodology Adopted	Merits	Demerits
6.	Minimal Wind Energy Generation System for DC Grids with Variable Structure Control	When compared to a normal proportional-integral (PI) controller, the sliding mode (SM) control will be more suited for the wind energy conversion system.	1) Non-linear controller capability. 2) A sliding mode controller is more capable of transient tracking than a PI.	PI control is no longer comparable to SM control.
7.	Wind Uncertainty's Implications on Grid Sensitivity to Arranging Overload Failures	To describe the sequence of cascading failures, the Markov model considers just electrical loads without accounting for thermal stability.	Algorithm for automatic power balance and island identification.	Slowly degrades the power system of the affected grid.
8.	Wind Energy Variance Protection in Microgrid Systems	A method for calculating wind power variations in the frequency domain and comparing them to load changes in the case of higher frequency power fluctuations.	Increases the pressure on the grid's frequency stability.	The impact on the stability and controllability of the power system.
9.	Windmill Inverter Robust Loop-Shaping Control Impacted by Grid Interaction	Robust control of wind turbine inverters using inductor-capacitor filters necessitates high-frequency switching, which is maintained low in high-power applications like as wind turbines to prevent losses.	To limit losses, use filters with a low frequency.	Inductance filters require high-frequency switching and high-power applications.
10.	Robust Grid-Synchronization and Axial Reactions Abilities for Weak Grid Stable Operation	Virtual synchronous generator (VSG) control typically involves many loops, with the converter's rapid switching frequency is required to decouple the dynamics of each loop. Finally, the virtual capacitor control is built and connected into the equipment controller to provide relevant inertia to the grid.	1)Low switching frequency 2)Faster response of switching frequency	Stability issues are occurred in without using virtual capacitor control.

Conclusion:

This article evaluated and addressed the issues of integrating wind energy into power systems, as well as the various solution techniques. Wind energy intermittency, reactive power support, voltage and frequency stability, power quality difficulties, fault ride-through capabilities, protection, cyber security, electricity market, planning, socioeconomic, and environmental challenges were among the issues covered. Wind power may regulate voltage as well as active power (frequency). When used as integrated generation, wind power plants can help minimize transmission and distribution losses. Other factors must be considered on a system-wide basis. Wind turbines have an impact on network voltage levels and electricity.

References:

1.S. D. Ahmed, F. S. M. Al-Ismail, M. Shafiullah, F. A. Al-Sulaiman and I. M. El-Amin, "Grid Integration Challenges of Wind Energy: A Review," in IEEE Access, vol. 8, pp. 10857-10878,2020,doi:10.1109/ACCESS.2020.2964896.

2. M. M. Islam, E. Hossain, S. Padmanaban and C. W. Brice, "A New Perspective of Wind Power Grid Codes Under Unbalanced and Distorted Grid Conditions," in IEEE Access, vol. 8, pp. 15931-15944, 2020, doi: 10.1109/ACCESS.2020.2966907.

3. Z. Xie, Y. Feng, M. Ma and X. Zhang, "An Improved Virtual Inertia Control Strategy of DFIG-Based Wind Turbines for Grid Frequency Support," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 9, no. 5, pp. 5465-5477, Oct. 2021, doi: 10.1109/JESTPE.2020.3039344.

4. Y. Yang, K. -T. Mok, S. -C. Tan and S. Y. R. Hui, "Low-power wind energy conversion system with variable structure control for DC grids," 2014 IEEE 5th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), 2014, pp. 1-6, doi: 10.1109/PEDG.2014.6878655.

5. Dynamic Stability Analysis and Improved LVRT Schemes of DFIG-Based Wind Turbines During a Symmetrical Fault in a Weak Grid, IEEE Transactions on Power Electronics, Liu, Ruikuo et al., IEEE Transactions on Power Electronics 35, 1, p303: doi.org/10.1109/TPEL.2019.2911346.

6. State Key Laboratory of Operation and Control of Renewable Energy & Storage Systems, China Electric Power Research Institute, Beijing 100192, People’s Republic of China: 10.1049/joe.2017.0498.

7. Q. Wang, C. B. Martinez-Anido, H. Wu, A. Florita and B. Hodge, "Quantifying the economic and grid reliability impacts of improved wind power forecasting," 2017 IEEE Power & Energy Society General Meeting, 2017, pp. 1-1, doi: 10.1109/PESGM.2017.8273967.

8. J. E. S. de Haan, J. Frunt and W. L. Kling, "Mitigation of wind power fluctuations in smart grids," 2010 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010, pp. 1-8, doi: 10.1109/ISGTEUROPE.2010.5638904.

9. Y. Ma, L. Tao, X. Zhou and X. Shi, "Analysis and Control of Fault Ride-Through Capability Improvement for Wind Energy Conversion System Using Linear Active Disturbance Rejection Control with Correction Link," in IEEE Access, vol. 8, pp. 73816-73827, 2020, doi: 10.1109/ACCESS.2020.2987103.

10. S. Sang, C. Zhang, X. Cai, M. Molinas, J. Zhang and F. Rao, "Control of a Type-IV Wind Turbine with the Capability of Robust Grid-Synchronization and Inertial Response for Weak Grid Stable Operation," in IEEE Access, vol. 7, pp. 58553-58569, 2019, doi: 10.1109/ACCESS.2019.2914334.

11. R. K. Beniwal, M. K. Saini, A. Nayyar, B. Qureshi and A. Aggarwal, "A Critical Analysis of Methodologies for Detection and Classification of Power Quality Events in Smart Grid," in IEEE Access, vol. 9, pp. 83507-83534, 2021, doi: 10.1109/ACCESS.2021.3087016.