

Review of Wind Turbine System and its Impact for Grid Stability

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Abstract— This paper presents an overall perspective of wind power plants and grid integration. Various wind turbine systems with different generators are described, and different technical features are compared. The electrical topologies with grid requirement for grid stability of wind farms are summarized and the possible uses of grid stability with wind farms are given. Finally, the Hybrid power system aspect and its impact on grid stability and its requirements are discussed.

Keywords— Grid Stability, Wind Turbine Technology, Induction Generator, Grid Integration, Wind farm, Hybrid System.

I. INTRODUCTION

WIND power has become the world's fastest growing renewable energy source. The many benefits of the wind energy are environmental protection, economic development, diversity of the supply, rapid spread, transference and technological innovation, industrial scale electricity in network and the fact is that the wind does not pollute, it is abundant, free and unlimited. The world-wide wind power installed capacity has exceeded 120 GW and the new installation in 2008 alone was more than 27 GW. More than thousands of wind turbines operating, with a total nameplate capacity of 121,188 MW of which wind power in Europe accounts for 55% (2008). World wind generation capacity more than quadrupled between 2000 and 2006, doubling about every three years. 81% of wind power installations are in the US and Europe. The share of the top five countries in terms of new installations fell from 71% in

2004 to 62% in 2006, but raised to 73% by 2008 as those countries—the United States, Germany, Spain, China, and India—have seen substantial capacity growth in the past two years. By 2010, the World Wind Energy Association expects 160 GW of capacity to be installed worldwide, right from 73.9 GW at the end of 2006, implying an anticipated net growth rate of more than 21% per year. Wind power is often described as an “intermittent” energy source, and therefore unreliable. In fact, at power system level, wind energy does not start and stop at regular intervals, so the term “intermittent” is misleading. The output of aggregated wind capacity is variable, just as the power system itself is inherently variable.

In the past, wind turbine generators were disconnected from the system during faults [5]. Nowadays, there is an increasing requirement for wind farms to remain connected to the power system during faults, since the wind power lost might affect the system stability. Therefore, the wind turbine behavior during system performance and its influence in the system protection must be analyzed.

One of the most frequent irrelevant features about integrating wind energy into the electricity network is that it is treated in isolation. An electricity system in practice is modify like a massive bath tub, with hundreds of taps (power stations) providing the input and millions of plug holes (consumers) draining the output. The taps and plugs are opening and closing at all the time. For the grid operators, the task is to make sure there is enough water in the tub to maintain system security. It is therefore the combined effects of all technologies, as well as the demand patterns, that matters. The specific nature of wind power as a distributed and variable generation source requires specific infrastructure investments and the implementation of new technology and grid management concepts. High levels of wind energy in system can impact on grid stability, congestion management and transmission efficiency and transmission adequacy. A grid code covers all material technical aspects relating to connections to, and the operation and use of, a country's electricity transmission system. They lay down rules which define the ways in which generating stations connecting to the system must operate in order to maintain grid stability.

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The paper describes an overview of survey of Grid Integration and power stability using hybrid system. . In this paper, the overview of wind turbine technology is in part1. Introduction of wind farm and Introduction of grid stability and its requirements is presented in the Part-3 & Part-4. The literature survey of grid stability and literature survey of grid stability with wind form are in the Part-5 & Part-6. Introduction and survey of hybrid wind power system and its impact on grid stability are presented in part-7 and finally concluded.

II. REVIEW OF WIND TURBINE TECHNOLOGY

[1]The main components of a wind turbine system are illustrated in Fig. 1, including turbine rotor, gearbox, generator, power electronic system, and a transformer for grid connection. Wind turbines obtain the power from wind by means of turbine blades and it's converted to mechanical power. It is important to control and limit the converted mechanical power during higher wind speeds. The common way to convert the low-speed, high-torque mechanical power to electrical power is using a gearbox and a generator with standard speed. The gearbox connects the low speed of the turbine rotor to the high speed of the generator, & gearbox is not be necessary for multi pole generator systems

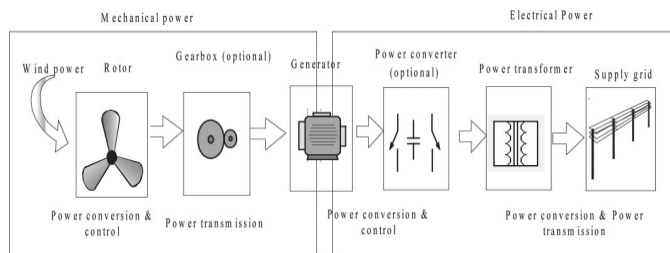


Figure 1: wind turbine system

The generator converts the mechanical power into electrical power, which is fed into a grid possibly through power electronic converters, and a transformer with circuit breakers and electric meters. The two most common types of electrical machines used in wind turbines are induction generators and synchronous generators. Induction generators produce electrical power when its shaft is rotated faster than the synchronous frequency of the equivalent induction motor. Induction generators are used in wind turbines due to their ability to produce power at varying rotor speeds. Induction generators are mechanically and electrically simpler than other generator types. They are also more rugged, requiring no brushes or commutators. Induction generators are not self-exciting, means they require an external supply to produce a rotating magnetic flux. The external supply can be supplied from the electrical grid or from the generator itself, when it starts producing power. The rotating magnetic flux from the stator induces currents in the rotor, which also produces a magnetic field. If the rotor turns slower than the rate of the rotating flux, the machine acts like an induction motor. If the

rotor is turned faster, it acts like a generator, producing power at the synchronous frequency. In induction generators the magnetising flux is established by a capacitor bank connected to the machine in case of standalone system and in case of grid connection it draws magnetising current from the grid. It is mostly suitable for wind generating stations as in this case speed is always a variable factor.

[2]A "synchronous" generator runs at a constant speed and draws its excitation from a power source external or independent of the load or transmission network it is supplying. A synchronous generator has an exciter that enables the synchronous generator to produce its own "reactive" power and to also regulate its voltage. Synchronous generators can operate in parallel with the utility or in "stand-alone" or "island" mode. Synchronous generators require a speed reduction gear. Customers are worried about future blackouts and having an increased power reliability should only consider cogeneration and regeneration power plants that have SYNCHRONOUS generators. Additionally, systems with synchronous generators can provide up to 100% of the facility's power, whereas induction generators can only supply about 1/3 of the facility's power requirements.

III. SCHEME FOR ELECTRIC GENERATION

In this section it is presented the several schemes for electric generation has been disused. There are many scheme developed in the recent past year. According to the operation characteristics and control technology of the generator, the wind generating set can be divided into two categories.

- Constant speed constant frequency system.
- Variable speed constant frequency system.

1) Constant speed constant frequency system.-

Constant speed drive has been used for large generator connected directly to the grid where constant frequency operation is essential. Constant speed constant frequency generating set only run in a fixed speed can reach the highest efficiency, when the wind speed changes wind generating set will be biased running away from the best speed, resulting in decreased operating efficiency. With the development of technology, this type of wind generating set will gradually withdraw from the market, because of output of electric power quality is poorer, power factor is lower, at the same time, when the assumption of infinite power grid does not exist, each wind generating set running state adjustment will have a great influence on local power grid. As an exam now we discusses about Constant speed squirrel cage induction generator. The popular schemes to obtain constant speed and constant frequency output are as follows.

a) Constant speeds squirrel cage induction generator

Constant speed wind turbines are equipped with squirrel cage induction generators directly connected to the grid (Fig. 2). The rotational speed of the rotor is practically fixed, since they operate at a slip around 1%. Since the induction machine

absorbs reactive power from the grid, connection of compensating capacitor banks at the wind turbine (or wind farm) terminals is required. Their aerodynamic control is based on stall, active stall or pitch control.

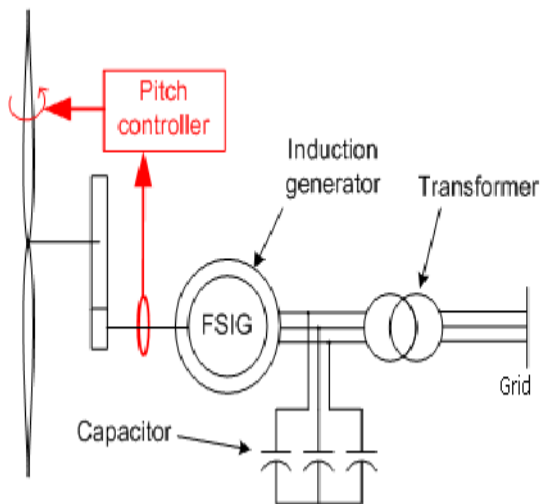


Figure 2: Fixed speeds squirrel cage induction generator

2) Variable speed constant frequency system-

Variable speed constant frequency system is typical for most small wind generators used in autonomous application, generally producing variable frequency and variable voltage output. according to key components has several different classification methods: In accordance with the availability of gear box can be divided into common type (with gear box) and direct-drive-based (no gear box); According to the type of generator can be divided into induction generator type, permanent magnet synchronous generator type, doubly-fed generator type, switched reluctance generator type, etc.; in accordance with the form of power converter can be divided into full power AC-DC-AC type, dual PWM converter type ,matrix converter type.[4, 7, 9, 52, 8] The popular schemes to obtain constant frequency output are as follows.

a) Doubly-fed induction generator

The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency differs from the grid frequency (50 or 60 Hz). By controlling the rotor currents by means of converter it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generators turning speed. The control principle used is either the two-axis current vector control or direct torque control (DTC). DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator. The doubly-fed generator rotors are typically wound with from 2 to 3 times the number of turns of the stator. This means that the rotor

voltages will be higher and currents lower. Thus in the typical $\pm 30\%$ operational speed range around the synchronous speed the rated current of the converter is accordingly lower leading to a low cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher rated rotor voltage. Further, the voltage transients due to the grid disturbances (three- and two-phase voltage dips, especially) will also be magnified. In order to prevent high rotor voltages - and high currents resulting from these voltages - from destroying the IGBTs and diodes of the converter a protection circuit (called crowbar) is used. A doubly fed induction machine is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in wind power applications. Firstly, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances (low voltage ride through, LVRT). Secondly, the control of the rotor voltage and current enables the induction machine to remain synchronized with the grid while the wind turbine speed varies.

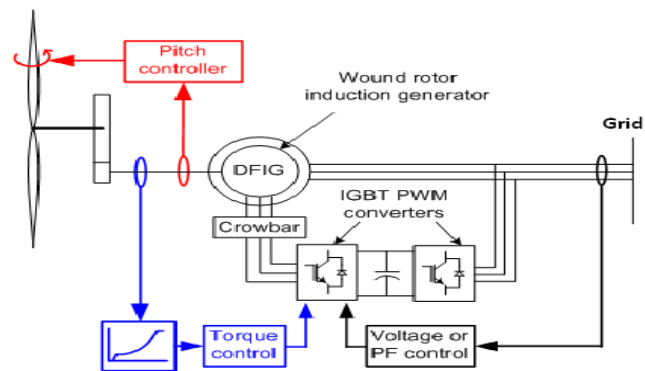


Figure 3: Doubly-fed induction generator

b) Direct drive synchronous generator

The drive system of modern wind energy converter is based on a simple principle: Fewer rotating components reduce mechanical stress and simultaneously increase the technical service life of the equipment. Maintenance and service costs for the wind turbine are lower (fewer wearing parts, no gear oil change, etc.) and operating expenses are reduced.

The rotor hub and annular generator are directly connected to each other as a fixed unit without gears. The rotor unit is mounted on a fixed axle, the so-called axle pin. Compared to the conventional geared systems which have a large number of bearing points in a moving drive train, the direct drive system has only two slow-moving roller bearings. The reason for this is the low speed of the direct drive. Synchronous generators are excited by an externally applied dc or by permanent magnets (PMs). There is considerable interest in

the application of the multiple-pole synchronous generators (either with PM excitation or with an electromagnet) driven by a wind-turbine rotor without a gearbox or with a low ratio gearbox. Synchronous machines powered by wind turbines are not directly connected to the ac grid because of the requirement for significant damping in the drive train. The use of a synchronous generator leads to the requirement for a full rated power electronic conversion system to decouple the generator from the network.

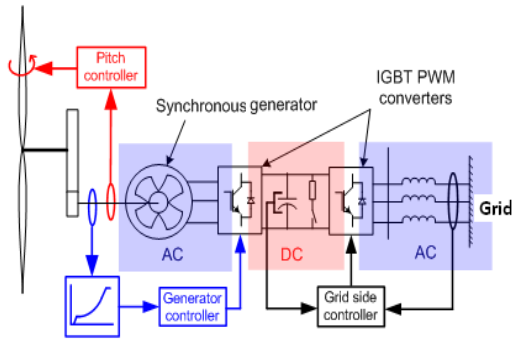


Figure 4: Direct drive synchronous generator

c) Matrix Converter

Matrix converter is a new type of "green" converter. Besides necessary to eliminate the small size switches ripple frequency filters, it does not contain any passive components. If there is the implementation of control algorithm, it does not need switch snubber circuit. Through bi-directional switch conduction and turn-off, three-phase AC input of any one phase can be connected to the three-phase AC output to any one phase. Matrix converter input side also need three-phase inductor capacitor (LC) filter to filter out input current caused by switching action of the high-frequency harmonics. [52]

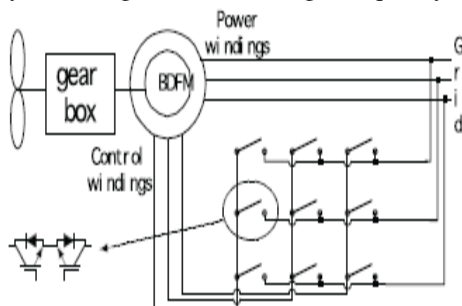


Figure 5: Matrix converter doubly-fed motor power system

IV. INTRODUCTION OF WIND FARM

A wind farm is a group of wind turbines in the same location used for production of electric power. Individual turbines are interconnected with a medium voltage (usually 34.5 kV) power collection system and communications network. A large wind farm may consist of a few dozen to several hundred individual wind turbines, and cover an extended area of hundreds of square miles (square kilometers), but the land

between the turbines may be used for agricultural or other purposes. A wind farm may be located off-shore to take advantage of strong winds blowing over the surface of an ocean or lake. The "wind park effect" refers to the loss of output due to mutual interference between turbines. Wind farms have many turbines and each turbine extracts some of the energy of the wind. Where land area is sufficient, turbines are spaced three to five rotor diameters apart perpendicular to the prevailing wind, and five to ten rotor diameters apart in the direction of the prevailing wind, to minimize efficiency loss. The loss can be as low as 2% of the combined nameplate rating of the turbines. In a large wind park, due to "multiracial" effects between individual rotors, the behavior deviates significantly from Kolmogorov's turbulence scaling for individual turbine. Utility-scale wind farms must have access to transmission lines to transport energy. The wind farm developer may be obligated to install extra equipment or control systems in the wind farm to meet the technical standards set by the operator of a transmission line. The company or person that develops the wind farm can then sell the power on the grid through the transmission lines and ultimately chooses whether to hold on to the rights or sell the farm or parts of it to big business like GE, for example. The Wind farm is of 3 types, onshore, near shore and Offshore. Onshore turbine installations in hilly or mountainous regions tend to be on ridgelines generally three kilometers or more from the nearest shoreline. Near shore turbine installations are on land within three kilometers of a shoreline or on water within ten kilometers of land. And offshore wind development zones are generally considered to be ten kilometers or more from land. Offshore wind turbines are less obtrusive than turbines on land, as their apparent size and noise is mitigated by distance. Because water has less surface roughness than land (especially deeper water), the average wind speed is usually considerably higher over open water. Capacity factors (utilization rates) are considerably higher than for onshore and nearshore locations. In order to take into account the aerodynamic effects associated to the layout of wind turbines in the farm, the scheme of Fig. has been considered. The wind turbines of the first row of M turbines take a part of the kinetic energy of the wind. Therefore, the wind speed for the second row is reduced, and so on in the following rows.

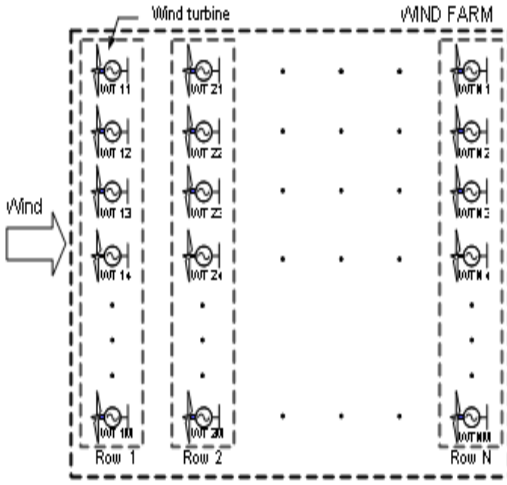


Figure 6: Layout of wind form

V. INTRODUCTION OF GRID STABILITY AND ITS REQUIREMENTS

The connection of large wind turbines to the grid has large impact on grid stability. The increased penetration of wind energy into the power system over the last decade has therefore led to serious concern about its influence on the dynamic behavior of the power system. As sketched in Fig.1, the main attention in the grid requirements is drawn to the fault ride-through and power control capabilities of large wind farms. The different characteristics from the different grids in each country cause that the behavior of the wind farm has greater or smaller influence in the stability of the system. For that reason the demanded requirements vary from one country to other and there are international organisms that work on surrounding of requirements that include the different exigencies. The squirrel cage induction generator of the constant speed systems always consumes reactive power. The consumption depends on the voltage and generated active power. In most of the cases this consumption is compensated by capacitors. By adding capacitors the impact of the wind generator is reduced. However, controllable reactive power sources are needed to fulfill the requirements, such as switched capacitor banks, STATCOM and SVC. In doubly fed induction generators the reactive power generation can be controlled by the rotor currents. In full converter topologies the generator is fully decoupled from the grid. The power exchange is not determined by the properties of the generator but by the characteristics of the grid side converter. The generator and the grid side power factors can be controlled independently.

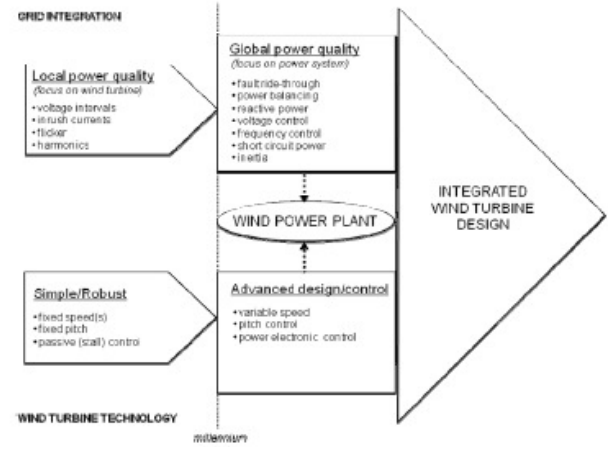


Figure 7: Wind Power Plant and Grid Integration

A. Fault ride-through capability

The fault ride-through requirement has been imposed in order to avoid significant loss of wind turbine production in the event of grid faults. Up to 7-8 years ago, wind turbines were only required to be disconnected from the grid when a grid fault was detected, in order thus to avoid large inrush currents when the voltage recovered. However, with the increased capacity of wind power in the power system over the years, such a disconnection of wind turbines could generate control problems of frequency and voltage in the system, and as worst case a system collapse. In case of dips above the limit line of Fig. 7, wind turbines must remain in operation, whereas they can disconnect in the event of dips below this limit. The voltage prescribed in Fig. 7 generally corresponds to the voltage at the grid connection point and the voltage dip may either be symmetric or correspond to the maximum of the phase voltages at this point, depending on the particular code requirements. FRT curves are similar to Fig. 7 although their quantitative characteristics vary among different systems.

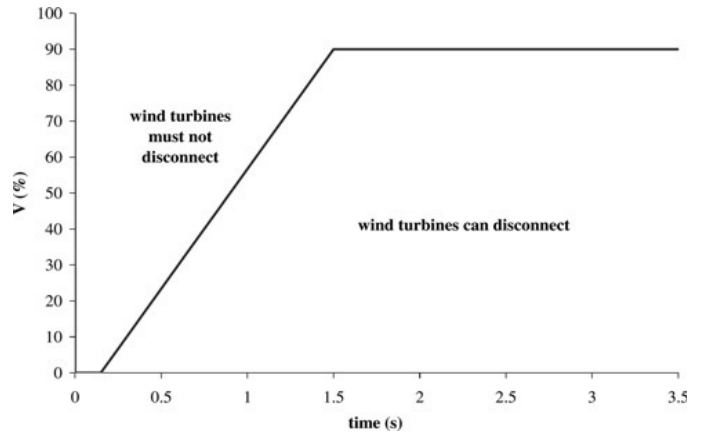


Figure 8: Typical limit curve for FRT requirements

A summary of the fault ride-through requirement in different national grid codes is given in TABLE 2. More demanding appear to be the requirements of the German, UK, Nordic, Danish, Belgian, Hydro-Quebec, Swedish and New Zealand

grid codes, which stipulate that wind farms must remain connected during voltage dips down to 0%. Another important difference lies in the active power restoration rates specified by the German and British/Irish grid codes: whereas the British code requires immediate restoration (at 90% in 0.5 s after voltage recovery), E.ON Nets requires restoration with a rate at least equal to 20% of the nominal output power (reaching 100% in 5 s after voltage recovery).

Grid code	Fault duration (ms)	Fault duration (cycle)	Min voltage level (% of V_{nom})	Voltage restoration (s)
German	150	7.5	0	1.5
UK	140	7	0	1.2
Ireland	625	31.25	15	3
Nordel*	250	12.5	0	0.75
Denmark (<100kV)	140	7	25	0.75
Denmark (>100kV)	100	5	0	10
Belgium(large voltage dips)	200	10	0	0.7
Belgium(small voltage dips)	1500	75	70	1.5
Canada(AESO)	625	37.5	15	3
Canada(Hydro-Quebec)	150	9	0	1
USA	625	37.5	15	3
Spain	500	25	20	1
Italy	500	25	25	0.25
Sweden(<100MV)	250	12.5	25	0.25
Sweden(>100MV)	250	12.5	0	0.8
New Zealand	200	10	0	1

Table 1: Summary of National Fault Ride-Through Requirements- [17]

*The **NORDEL** was a cooperation organization of the electricity transmission companies that operate the wide area synchronous grid of the Nordic countries of Finland, Sweden, Norway and Eastern Denmark

B. Power Control Capability

The power control ability means mainly that the wind turbines have to share, for shorter or longer periods, some of the duties carried out traditionally by conventional power plants, such as regulating active and reactive power and performing frequency and voltage control on the grid. These requirements refer to the ability of wind farms to regulate (usually, but not exclusively, reduce) their power output to a defined level (active power curtailment), either by disconnecting wind turbines or by pitch control action. In addition, it is required from wind farms to provide frequency

response that is to regulate their active output power according to the frequency deviations. The powers control requirements two different control and stability aspects. These are *active power/frequency control*, *reactive power/voltage control and dynamic stability*.

1) Active power/frequency control:

It is a fast, automatic global adjustment of power to frequency. The grid codes of the different countries demand the wind farms to have the ability of active power curtailment. Germany, with a ramp rate 10% of grid connection capacity per minute. Ireland, with a ramp rate 1–30 MW/min. Denmark, with a ramp rate 10–100% of rated power per minute.

2) Reactive Power/Voltage Control Ability:

Voltage regulation in power systems is directly related to the control of reactive power. The recent grid codes demand from wind farms to provide reactive power control capabilities, often in response to the power system voltage, much as conventional power plants. The reactive power control requirements are related to the characteristics of each network, since the influence of the reactive power injection to the voltage level is dependent on the network short-circuits capacity and impedance. Fig 8 compares the permissible wind farms power factor range (based on rated power) in relation to grid voltage, according to the German (grey line) and British (light grey line) grid codes. The nominal voltages are 380, 220, 110 kV for onshore wind farms and 155 kV for offshore wind farms in Germany and 400, 275 kV for Great Britain.

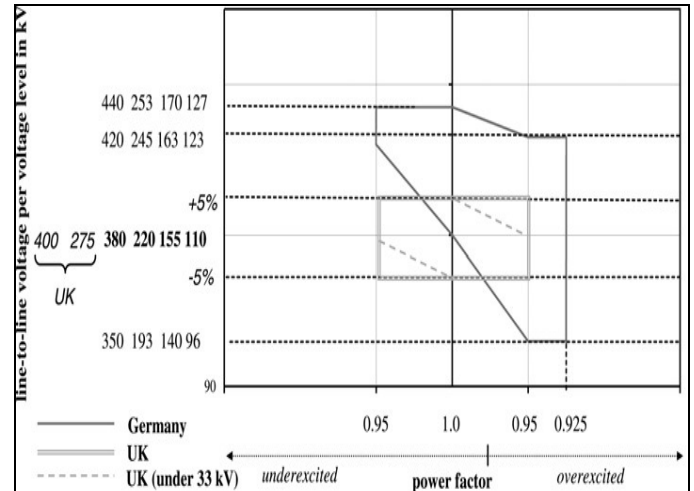


Figure 9: Requirements for power factor variation range in relation to the voltage, according to the German and British grid codes

3) Dynamic Stability:

It is focus on the ability of wind farms to withstand some specific grid faults without being disconnected. The Grid

Code valid until 2003 for wind turbines increases the supply risk and endangers dynamic grid stability if a fault should occur. The wind turbines affected should be brought in line as soon as possible with the Grid Code which has been valid since 2004.

C. Requirements for Reactive Current Supply during Voltage Dips:

Some grid codes prescribe that wind farms should support the grid by generating reactive power during a network fault, to support and restore fast the grid voltage. Wind farms support grid voltage with additional reactive current during a voltage dip, as shown in Fig. 9, as well as via increased reactive power consumption in the event of a voltage dip. The voltage control must take place within 20 ms (one cycle) after fault recognition by providing additional reactive current on the low-voltage side of the wind turbine transformer, amounting to at least 2% of the rated current for each percent of the voltage dip.

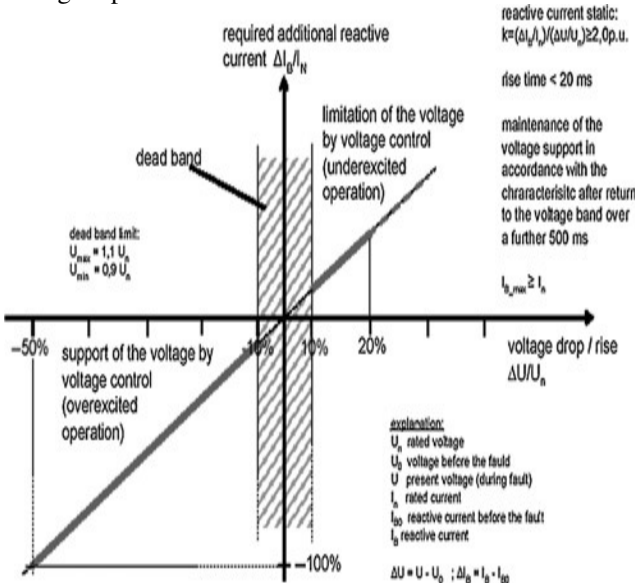


Figure 10: Reactive output current during voltage disturbances

VI. LITERATURE SURVEY OF GRID STABILITY

A. Fixed speeds squirrel cage induction generator:

In [7] paper presents a comparison of static and dynamic continuation power flow techniques, time domain simulations and quasi-static time domain simulations for voltage stability analysis of networks with high wind power penetration. Three wind turbine models are considered, namely, constant-speed induction generator; doubly-fed induction generator; and direct drive synchronous generator. Several simulations are solved in order to assess the behavior of wind turbine models and the reliability of voltage stability techniques. Author taken case study based on a 40-bus network that models an existing distribution system with one high voltage feeder.

In [14] the author used topology for constant speed systems is the squirrel cage asynchronous generator connected to the grid. The sliding is usually limited to 2% so the rotor speed is almost constant. A popular option is the use of a double stator winding, one with a low number of poles to use at high wind speeds and another one with a greater number to be able to work at smaller wind speeds.

B. Doubly-fed induction generator:

In the paper [1] author discuss various aspect related to turbine and conclude that Wind turbines with induction generators (IG) are only used by small wind farms because they lack reactive power controlling. Wind turbines with doubly fed induction generators (DFIG) have been installed more widely than wind turbines with direct drive (DD) because they need relative lower initial capital, but wind turbines with DD can support the grid voltage better than DFIG during faults. If maintenance is considered, their costs are similar in the longer term for all turbine types.

In the [6] the methods to validate WECC Generic Models are presented. According to author, the models tested and validated are positive sequence/transient stability models with the time frame of interest for simulations between 1 to 20 seconds. The validation method described for applicable for all the types of wind turbine generators. For a single or two turbine representations, we lose some of the details of the wind power plant, due to the fact that diversity in the wind power plant is not represented (line impedance, wind speed, relay protection etc). Thus, we represent only the "average" turbines in the wind power plant. The preliminary results of the simulations demonstrated that a generic model of DFIG generators provides an adequate representation of the actual wind turbines under fault conditions. It is also shown that equivalencing the entire wind power plant with only two turbines does not degenerate the fault performance of the model. The voltage and frequency profile implemented in the GENCLS model seems to represent the fault sufficiently. Author suggested that work in progress, and will continue to find better ways to improve the validation methods to resolve some of the discrepancies between the simulation and measured data. Future work will include type 1, type 2, and type 4 generic wind turbine models being developed.

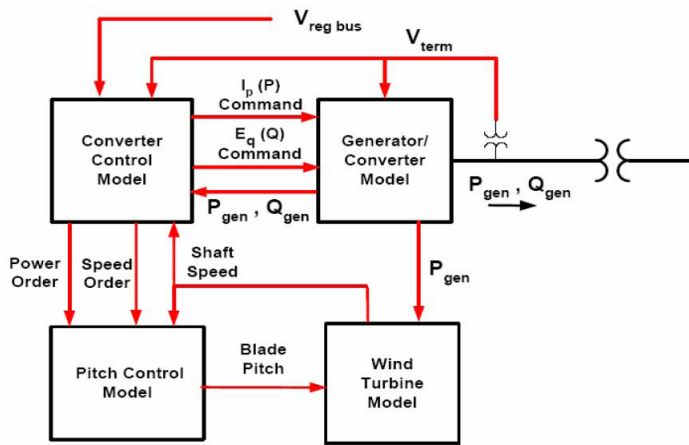


Figure 11: Block diagram of WECC generic DFAG model

In paper [12] generic model of a wind turbine with a double fed generator for grid stability studies is presented. The model takes-off in the required model performance rather than the physical structure and components of the wind turbine. Analysis shows that substantial reductions in model complexity can be achieved by extending some of the basic assumptions for a grid stability model into model simplifications. In spite of large variation in model complexity, a case study in Power Factory reveals no significant performance variations when the performance oriented model is compared to a far more complex component-oriented model. Performance evaluation using the IEEE 9-bus system shows no significant difference in system behavior comparing the performance model presented in this paper to a conventional and far more complex component oriented model.

Taking the performance based modeling approach of developing the WTG model requires detailed knowledge of the WTG as well as the power system analysis to be carried out.

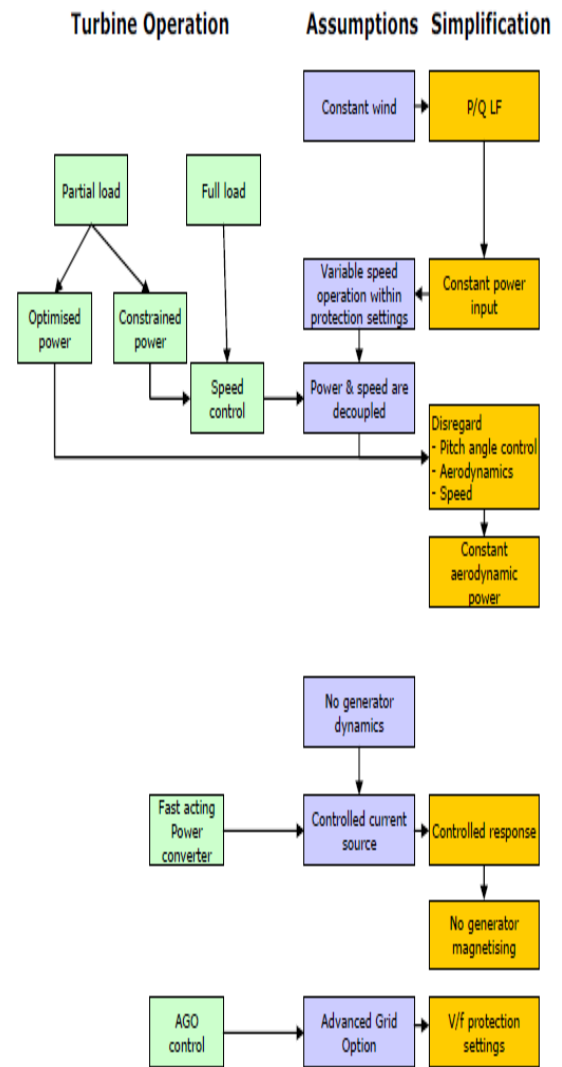


Figure 12: Chain assumptions and simplifications following the main assumption of constant wind input to the model

Author suggested that Generic models representing the dynamics of relevance for power system stability analysis should be developed for large-scale studies. Models should not be developed for each manufacturer, but an agreed modelling approach should be sought for the primary wind turbine topologies, and these models should be made available to the industry at large. These generic models should be validated using staged tests and an acceptable level of modelling error agreed. This approach would allow large-scale system studies to be carried out.

In [9] the research project study of the dynamics and control of distributed resources (DRs) in the deregulated electric power industry are presented. Wind turbine model was derived using a linearization technique coupled with the approximation of the wind turbine dynamics. Given that there was no readily available data for a straightforward data reduction procedure, the method developed by Justus was used and it proved to be successful based on the output profiles that were obtained for all the simulations. All of them

were comparable to the profiles of other wind turbines that have been studied. This was a different and useful approach to wind turbine modeling. The author proposed future work is the non-linear dynamics simulated with this simple model are easily linearized, also suggested that several considerations must be made in order to design a PID controller using a linear model. The optimal region based on the balanced performance of the two minimization parameters shifts with the linearization point selection. Operating point selection for a linear model is critical to obtaining the best possible performance from this highly non-linear system.

In paper [10] the electrical part of a grid connected variable speed wind turbine is considered, which is equipped with a permanent magnet synchronous generator. The modeling of the generator and power converter, ensuring the connection to the grid, are checked experimentally on a prototype, both for dynamic system analysis and operating limits investigation. Measurements as well as control functions are performed by using a microprocessor. The simulation and experimental results are used in the development of a 25 kW wind turbine, in the frame of a research project.

In paper [15] the grid impact of a new technology of variable speed wind turbine is analyzed. The concept of the directly grid coupled synchronous generator with hydro dynamically controlled gearbox (Win Drive®), which is developed and manufactured by Voith Turbo, is presented and the implementation of a detailed dynamic model 2 MW wind turbine including the Voith Win Drive® in the simulation software Dig SILENT *Power Factory* is described. For investigating the behavior of the turbine models and its compliancy with existing grid codes, a detailed model of a 50 MW wind farm consisting of 25 individual wind turbines with typical layout is used. The dynamic model is valid over a wide time range from some milliseconds up to several minutes. According to author Wind-farms based on directly connected synchronous generators support the voltage and stabilized the system by increasing the short-circuit level. Especially in weak areas, this might be of very high importance.

VII. LITERATURE SURVEY OF GRID STABILITY WITH WIND FORM

In the paper [2] author discuss that the possible to develop a set of equations describing the behavior of the wind turbine. Furthermore, vector control strategy has been examined for controlling active and reactive power of grid, stator and rotor sides. The behavior of the system was investigated during steady state and transient conditions. This paper considers a grid-connected system; a further paper will describe a stand-alone system with experimental evaluation.

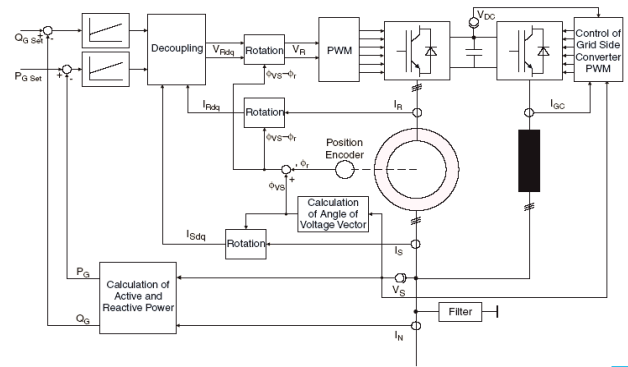


Figure 13: Vector control strategy of DOIG

In the paper [3], the model aspects and the impact of wind power onto a weak power system have been described. A wind system model was presented that takes into account factors such as a rapidly varying turbulence component of the wind and the aerodynamic effects associated to the layout of wind turbines throughout the farm. A test system was used and case studies for different instances of wind farm operation were analyzed, with an aim at evaluating the interaction of the wind farm with the power system. The test system to evaluate the interaction of the wind farm with the power system is as a single-line diagram. Such a system features a substation, represented by a Thevenin equivalent with a short circuit power of 100MVA, which feeds a transmission network operating at 132kV/50Hz.

This paper [4] presents a model-based predictive control (MBPC) strategy for the field oriented control of a double output induction generator (DOIG). The control region is defined over two wind profiles: average wind speeds below and above equipment rating, subject to assigned constraints of the maximum allowable system frequency fluctuations and the power limit of the wind energy conversion system (WECS). To meet the objectives of maximizing energy capture and alleviation of drive train fatigue loads, controller design is based on perform ability models of the WECS's components. Simulations verify the proposed paradigm achieves regulation of torsional dynamics while maintaining optimal operation. MBPC employs online optimization of future trajectory subject to constraints using quadratic programming for cost function minimization, and execution of the first step of the control sequence. observed that the system outputs follow the references with negligible steady state errors at both rated and above-rated mean wind speeds. Author stay that Future research will focus on transient analysis and testing the effects of modulation torques such as tower shadowing on the modeling approaches.

In [5] a novel approach of pitch regulated wind turbine using intelligent soft starter based induction generator is presented. Neuro Fuzzy approach has been used as intelligent tool in soft starter to estimate thyristors firing angle accurately so as to integrate the generator to the grid smoothly. Various wind turbine models such as 600kW and 1000kW are taken for simulation and simulation results have been presented to prove the proposed methodology. Low Voltage Ride through (LVRT) capability of proposed methodology in 1 MW wind

turbine model is also presented in this paper to prove the reliability of proposed method.

In [8] the wind turbine instantaneously generated power and voltages at the point of common connection (PCC) with grid are simulated by considering all the aero dynamical and mechanical effects, which could affect them. The inherent effect of the wind speed on the entire blade swept area is simulated in the model of the wind speed. The generated power is obtained by the simulation of the wind speed time series into a wind turbine model. The flicker meter model which expresses voltage fluctuations is simulated according to the IEC standard 61000-4-15. From simulation results, voltage fluctuations are widely affected by the grid strength and X/R ratio of grid internal impedance. The flicker emission is decreased with higher fault levels. The risk of voltage fluctuation increases in the resistive grids. The wind turbine operating point and the Q-P characteristic of the generator determine the point of minimum flicker emission. The trend of flicker variation with the mean wind speed depends mainly on the wind turbine power curve. The power variability and consequently flicker emission increases with turbulence increase.

In [11] discusses the modeling and simulation of a wind farm including a actual wind speed measurements to investigate the fluctuations in the real power of the induction generators. The wind farm's output power oscillates due to the variable wind speed. This coupled with the fact that wind farms are generally connected to weak systems, results in both frequency oscillations and voltage flicker. The simulations show that the SMES can help to improve both SMES system. Transient models for the WECS and SMES system have been developed in EMTP. The study considers the transient stability and the controllability of the real power, which contributes to an overall improvement in the system's performance.

In [13] presented the adequacy of Alternative Transients Program (ATP) Draw to accomplish the studies necessary to evaluate the impact of connecting wind farms to power systems, since the elements of the wind farm are adequately modeled. The simulations presented show the possibility to evaluate the consequences of the possible disturbances, as well as to deduce the solutions and verify their use. Further, the developed tools allow the investigation of applying control strategies to the converters taking into consideration the power quality.

This paper [16] addresses the problem of predicting a wind farm's power generation when no or few statistical data is available. The study is based on a time-series wind speed model and on a simple dynamic model of a doubly-fed induction generator wind turbine including cut-off and cut-in behaviors'. The wind turbine is modeled as a stochastic hybrid system with three operation modes. Numerical results, obtained using Monte- Carlo simulations, provide the annual distribution of a wind farm's active power generation. For

different numbers of wind turbines, we compare the numerical results obtained using the dynamic model with those obtained considering the wind turbines steady-state power curve. Simulations show that considering the wind turbines dynamics does not significantly enhance the accuracy of the annual distribution of a wind farm generation.

VIII. INTRODUCTION AND SURVEY OF HYBRID WIND POWER SYSTEM AND ITS IMPACT ON GRID STABILITY

Now days, the concept of a widely using wind power in combination with Hybrid wind power system is always discussed recently, such as wind power with photovoltaic power, wind power with fuel cell or wind power with heat production, some hybrid power system are also made up of more than 3 kinds of energy resources. The main purpose of hybrid power system is to overcome the intermittency and uncertainty of wind energy and to make the power supply more reliable. Presently, 2 kinds of wind power hybrid systems are the focused upon wind power with fuel cell and wind power with photovoltaic power.

A. Wind Power with Fuel Cell

Hybrid wind power with fuel cell can avoid the disadvantage of wind power intermittency, since fuel cell can act as an energy barrier and adjust the power output effectively. In the literature the issues about the this kind of hybrid system are discussed including: modeling research in control and operation.

B. Wind Power with solar energy

Wind power and solar energy are always combined into a hybrid system, especially for the power supply for remote areas where the cost of transmission line is too high. Also, another advantage of this kind of hybrid system is that they are both renewable energies, which is compatible to the environment. In, the issues of this kind hybrid system are discussed, including planning, operation strategy, control system, modeling, etc.

In [23] these paper the modeling and performance analysis of wind/diesel hybrid generating system. Such configurations are typical for remote rural communities which are disconnected from the larger power grid, such as those located on islands or in forests. Controllers are designed to ensure operation of the wind and diesel units in a cooperative manner, in order to reduce the fossil-fuel consumption of the diesel generator. The system has been simulated using PSCAD/EMTDC for different wind speed variations.

In paper [24] discusses the optimization of the hybrid system in context of minimizing the excess energy and cost of energy. The hybrid of pico hydro, solar, wind and generator and battery as back-up is the basis of assessment. The configuration of the hybrid system is derived based on a theoretical domestic load at the remote location and local solar radiation, wind and water flow rate data. Three demand loads are used in the simulation using HOMER to find the optimum combination and sizing of components.

This [48] paper discusses a new analytical approach of reliability evaluation for wind-diesel hybrid power system with battery bank for power supply in remote area. The proposed approach is developed on the basis of the discrete speed frame analysis of the Weibull wind speed distribution. By employing wind speed frame analysis, an analytical model of wind-diesel with this issue. All these models can be roughly classified by hybrid system is developed, which deals with system outage as a result of component failure and wind speed fluctuation.

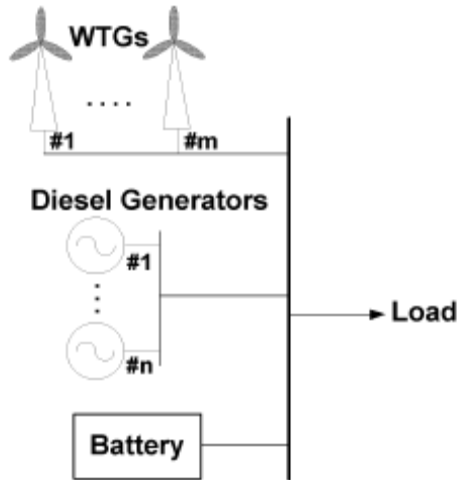


Figure 14: A typical wind-diesel power system incorporating battery bank.

The main aspect of this technique is studying wind turbine generator performance within each speed on the Weibull distribution curve. Consequently, no continuous time series analysis or calculations need to be conducted in this method. This time-irrelevant attribute thereby can save the large amount calculation time spent on seriatim calculating and it also makes model quite simple.

The paper [49] describes the impact of installation of wind farms on system reserve and reliability from a long term planning point of view. A reliability-based reserve allocation method is proposed to determine the reserve required for a power system with high wind power penetration. A multi-state wind farm model and a multi-state load model are combined to represent the fluctuation of wind speed, outages of wind turbine generators and uncertainty of load by using universal generating function techniques. The IEEE RBTS has been modified to illustrate the applications of the proposed method. The system studies show that the technique be easily used to determine the hydro/thermal reserve for a given load and wind penetration.

IX. CONCLUSION

This paper gives a survey on impact of wind power on grid stability. In the paper also hybrid wind power systems considering the fuel cell and photovoltaic energies are

reviewed as well. Papers were selected to emphasize the diversity of forecasting methods and the problems that wind generators will suffer from.

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