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A Review On Comparative Analysis Between PI and FUZZY Based STATCOM For Wind Power Application

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Abstract— Limited fossil fuel resources have directed the mankind to find alternative ways to satisfy the future energy needs and Optimizing the utilization of the existing resources. The renewable energy technologies, in this regard, are likely to be the potential solution for future energy requirements. Various renewable energy sources such as wind, hydro, biomass, etc, are going to play an important role in sustainable energy development.

In the past, the amount of wind power integrated into large- scale power systems forms only a small part of the total electrical generation. Most of the electricity is still being generated by conventional sources, such as thermal, nuclear and hydro generators. Therefore, it was not necessary to require wind turbines to provide voltage and frequency support. During a large disturbance, such as a grid fault, the wind turbines are typically rapidly disconnected from the power network and reconnected when normal operation has been resumed. Under these conditions, the modern power system has to confront some major operating problems, such as voltage regulation, power flow control, transient stability, and damping of power oscillations, etc.

Nowadays, various flexible FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillation. Some of those are used also to improve transient and dynamic stability of wind power generation system (WPGS). Static synchronous compensator (STATCOM) based on the voltage source converter (VSC) PWM technique is use to Stabilize grid connected squirrel cage wind generator system.

In this work , the comparison of the controllers such as PI and FUZZY will be Presented, on the basis of their performance to maintain the speed of the squirrel *cage induction generator (SCIG) constant for different wind speeds and will be simulated by using MATLAB/ SIMULINK .*

Keywords- *Flexible AC Transmission Systems (FACTS), Wind power generation system (WPGS),Static synchronous compensator (STATCOM), voltage source converter (VSC), pulse width modulation (PWM), squirrel cage induction generator (SCIG), point of common coupling (PCC), static var compensator (SVC), dynamic voltage restorer (DVR), solid state transfer switch (SSTS), unified power flow controller (UPFC),fuzzy logic controller (FLC).*

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I. INTRODUCTION

Nowadays wind as a significant proportion of non-pollutant energy generation, is widely used. If a large wind farm, which electrically is far away from its connection point to power system, is not fed by adequate reactive power, it present major instability problem. Various methods to analyze and improve wind farm stability have been performed [1]. In recent years, there has been a worldwide growth in the exploitation of renewable energy, in particular wind energy. Up to now, most existing wind turbines are equipped with induction generators. In the induction generator, the amount of power converted depends on the magnitude of the grid voltage at the point of common coupling (PCC) with the grid. When a fault occurs somewhere in the grid, which causes a voltage drop at the PCC, the induction generator speeds up due to the unbalance between the mechanical shaft torque and the generator's electromagnetic torque. During this time, the induction generator draws more Reactive power from the grid and contributes further to the PCC voltage collapse [2].

Years before, wind farms forms only a small part of the total electrical generation. Conventional sources such as thermal, nuclear, and hydro generators are been used for generation of electricity. Therefore, it was not necessary to require wind turbines to provide voltage and frequency support. If a sudden large disturbance occurs such as a grid fault, the wind turbines are typically rapidly disconnected from the power network and reconnected when normal operation has been resumed. This is possible, as long as wind power penetration remains low. However, the penetration of wind power is increasing rapidly and is starting to influence overall power system behavior. Moreover, due to growing demands and limited resources, the power industry is facing challenges on the electricity infrastructure. As a consequence, it will become necessary to require wind farms to maintain continuous operation during grid disturbances and thereby support the network voltage and frequency.

Under such circumstances, the system faces problems like voltage regulation, power flow control, transient stability, damping of power oscillations, etc. Flexible AC transmission system (FACTS) devices [3] can be a solution to these problems. They are able to provide rapid active and reactive power compensations to power systems, and therefore can be used to provide voltage support and power flow control, increase transient stability and improve power oscillation damping. Suitably located FACTS devices allow more efficient utilization of existing transmission networks.

Recently voltage-source or current-source inverters based flexible AC transmission systems (FACTS) devices such as Static var compensator (SVC),Static synchrounous compensator (STATCOM), DVR, solid state transfer switch (SSTS) and unified power flow controller (UPFC) have been used for flexible power flow control, secure loading and damping of power system oscillation. Some of those are used also to improve transient and dynamic stability of WPGS. SVC is reported to improve the terminal voltage of induction generator by compensating the reactive power. But STATCOM has somewhat better performance compared to SVC for reactive power compensation, which is reported clearly in [4].

Among the FACTS family, the shunt FACTS devices such as the static synchronous compensator (STATCOM) [3] has been widely used to provide smooth and rapid steady state and transient voltage control at points in the network. It is also used to improve power system stability, by injecting or absorbing reactive power. This function of STATCOM needs some more supplementary input signals[3]. Several controllers have been used to perform this control strategy such as conventional PI controller.

Uncertainties exist in almost every physical system. Power systems are large scale system with high non linearity, so there is an considerable uncertainty in every part of them. Fuzzy logic performs as a powerful tool to confront these uncertainties [5].Fuzzy logic based control strategy for STATCOM is use to improve power system stability and performance. The fuzzy logic approach provides a model free method for STATCOM control and can be effective over a wide range of power system changes [6].

II. LITERATURE SURVEY

Interaction of Large Offshore Wind Parks with the Electrical Grid.

Erlich, Senior Member, IEEE, C. Feltes, F. Shewarega, Member, IEEE, and M. Wilch University Duisburg-Essen

This paper deals with the impact of increased wind power generation on the behaviour of the interconnected system in steady state as well as during and after a contingency situation. The issues specifically considered are performance during a severe short-circuit and frequency stability after a sudden loss of generation. The results of the short-circuit simulation are then evaluated vis-à-vis the grid code requirements placed on wind generating plants. Using a large interconnected system encompassing several conventional synchronous generators, the effect of increased wind power generation on the frequency stability of the system after a loss of generation has been discussed. It was found out that at the conceptual level there are a range of options which would place wind generating plants in a position to support system frequency in an emergency situation.

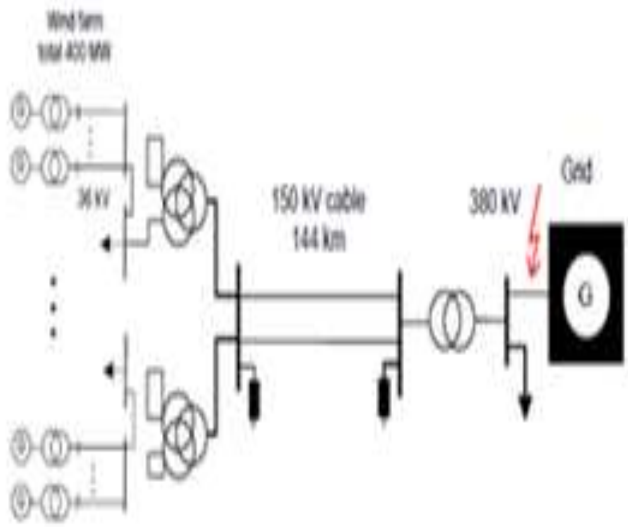

Fig 1. Simulated offshore wind farm

The dependence of wind on the prevailing weather conditions means that the installed capacity does not guarantee firm dispatch-able energy. As a result, traditional power stations with sufficient capacities must be held on hand to fill the gap. Following the emergence of wind as a major power technology during the last several decades, in addition to devising ways to overcome this drawback, the proper integration of wind turbines into the system by maintaining the existing reliability and performance standards has become an issue of immense interest.

In this paper, three phenomena were singled out for in-depth discussion, namely behavior of the wind generation plants in steady state, fault-ride through capability and frequency stability. Wind generation plants reduce the overall inertia of the system due to shielding by the converter. Wind plants also achieve a much faster real power rate of response as a result of the electrical control of the real power. On the other hand, in spite of the additional features that enable a swift voltage recovery, wind generators cannot achieve the same level of reactive power output as that of the conventional plants during fault.

The smaller inertia of wind turbines has another implication in that it leads to a steeper drop in frequency following a loss of generation. Wind generators with frequency dependent voltage control are able, not only to maintain the grid voltage, but also to provide a considerable contribution to frequency stability by utilizing the voltage dependency of the loads. The need for voltage control of wind generation plants therefore needs to be balanced against the advantage that a softer voltage characteristic offers in terms of frequency stability.

Impact of Wind Variability on Weakly Interconnected Power Systems.
Mounes Alhajali, Brendan Fox, Jason Kennedy and D. John Morrow, Member, IEEE

The inherent variability and uncertainty of wind power generation is a major issue for countries attempting to harness large quantities of wind-based renewable energy. Such properties of wind make optimal balancing of demand and generation a much more complex task. Clearly the flexibility of thermal plant in the electrical power system is of key importance, especially in smaller systems with high penetrations of wind power, as is the role of interconnectors with neighboring countries. This paper examines the power system of Ireland as a test case for systems with high wind penetrations and limited interconnection to neighboring countries, such that wind variability must be managed using indigenous methods. The analysis highlights problems other power systems will encounter as they in turn reach high penetrations of wind generation.

Feasible operation of a system with a high penetration of variable wind generation requires flexible generation, or interconnection with neighbouring systems, or a combination of the two. In the case of the Irish system, the prospect of interconnection will definitely help with system operation .Generation itself should be taken into account. The opportunity for import and export at times of wind power excess and deficit will consequently be limited.

Probabilistic Analysis for Maximizing the Grid Integration of Wind Power Generation.
Leonel de Magalhães Carvalho, Student Member, IEEE, Mauro Augusto da Rosa, Member, IEEE,Armando Martins Leite da Silva, Fellow, IEEE, and Vladimiro Miranda, Fellow, IEEE

This paper presents a sequential Monte Carlo simulation algorithm that can simultaneously assess composite system adequacy and detect wind power curtailment events. A simple procedure at the end of the state evaluation stage is proposed to categorize wind power curtailment events according to their cause. Furthermore, the dual variables of the DC optimal power flow procedure are used to identify which transmission circuits are restricting the use of the total wind power available. In the first set of experiments, the composite system adequacy is assessed, incorporating different generation technologies. This is conducted to clarify the usual comparisons made between wind and thermal technologies which, in fact, depend on the performance measure selected. A second set of experiments considering several wind penetration scenarios is also performed to determine the operational rules or system components responsible for the largest amount of wind energy curtailed. The experiments are carried out on configurations of the IEEE-RTS 79 power system.

This paper presented an algorithm, along with the estimation of the traditional loss of load indices, makes it possible to detect and estimate indices to characterize wind power curtailment events. A simple model that includes the operators dispatch preferences, when large portions of the generating capacity are intermittent, was included in the dispatch procedure. Moreover, an algorithm was proposed to detect whether wind curtailment events are due to the enforcement of the inertial constraint and/or load deficit, the failure and/or capacity limits in transmission circuits or the simultaneous occurrence of both of these events. Finally, based on the sensitivity coefficients of the equality constraints, it was shown that the circuits involved in the wind curtailment event can be identified, making it possible to assess useful statistics that can be useful in the planning process for the system.

Wind power curtailment events under a strategy of maximum usage of wind power were also analyzed. It was shown that, for the cases studied, the level of congestion for the transmission network does not limit the use of wind power as severely as the inertial constraint. Furthermore, the amount of wind energy curtailed has grown very rapidly with the amount of inertial load. It was observed that, when the penetration of wind power increases, the combination of the inertial constraint with insufficient load to accommodate the additional generating capacity may lead to huge quantities of wind energy not being used. Finally, there may be systems with more relevant transmission congestion events and, surely, the proposed approach will capture these characteristics and will allow system planners to adequately cope with them. The value of inertial load and the units capable of supplying it depend on the system. As stated previously, these are normally set according to the dynamic characteristics of the generating units and to the operational procedures adopted by the system operator.

New wind farms in the network will influence the dynamic behavior of the system and, consequently, the value of inertial load. Since the wind power not used increases with the inertial load, these new units must be able to ensure that the inertial load remains unchanged. Clearly, the inertial constraint model is a simple approximation that accounts for security issues when performing generating unit dispatch. Future work will focus on enhancing this model by developing a fast dynamic security assessment method, which helps decide, in an adaptive way, the minimum set of units required to guarantee the stability of the system.

A Laboratory Based Micro grid and Distributed Generation Infrastructure for Studying Connectivity Issues to Operational Power Systems.
O. A. Mohammed, Fellow, IEEE, M. A. Nayeem, Student Member, IEEE and A. K. Kaviani, Student Member IEEE

This paper presents an infrastructure and laboratory implementation of a hardware test-bed system emulating alternate sources and conventional power plant emulators connected as a complete power system. The distributed generation components were connected to the test-bed to study the issues of connecting alternates and various types of loads during operations. The various sources and loads can be connected in varying architectures through transmission and distribution lines as well as bus hardware emulators. Also SCADA, communication network and control system layers were developed and placed around the various test-bed components. Wind turbine model, PV array and micro turbine based generator were developed to emulate alternate resources and integrated with battery banks and flywheel based storage system. These emulators are real time hardware-in-the-loop models based on d SPACE control development modules and Simulink real time workshop. Lab view is also used along with measurement studio for control and communication applications. The system is intended for studying and analyzing the interconnection issues on the power system and micro grid due to interconnected operation and to develop solutions and devise better techniques for smart grid operation. Other agent modules for control, various flywheel models, wind emulators, PV arrays and Fuel Cell emulators can be connected to this system as additional resources. The response of the grid can be studied by their integration. The system is also intended to be used as an educational tool for students to become more familiar with the new concepts of Alternate and green energy and other issues related to the future power systems.Alternate source emulators were designed and developed.

Effects of FACTS devices on a power system which includes a Large wind farm.
WEI Qiao , student member , IEEE, Ronald G. harley ,Fellow IEEE, and Ganesh k . Venayagamoorthy , senior member, IEEE.

The power systems had to confront some major operating problems in voltage regulation, power flow control, transient stability, and damping of power oscillations, etc. Flexible AC transmission system (FACTS) devices can be a solution to these problems. This paper investigates the application of FACTS devices on a 12-bus multi machine power system including a large wind farm. STATCOM is added to this power network to provide dynamic voltage control for wind farm, dynamic power flow control for transmission lines control and improves transient stability.

Stabilization of Grid connected Wind Generator by STATCOM.
S.M muyeen , mohd. Abdul mannan , Dept of electrical engg. Kitami institute of technology , japan

A simple control strategy of STATCOM is adopted where only measurement of rms voltage at the wind generator terminal is needed i.e. there is no need of reactive power measurement. Fuzzy logic controller is used as the control methodology of STATCOM, rather than conventional PI. In this paper the STATCOM based on VSC PWM technique to stabilize grid connected squirrel cage wind generator system. FLC is used as the control methodology of STATCOM. The voltage sag and swell improvement of WPGS is compared with both fuzzy and PI controller WPGS. Comprehensive results are presented to assess the performance of the STATCOM connected with WPGS.

Fuzzy controlled STATCOM for Improving the power system Transient Stability.
A.Ghafouri, M.R.Zolghadri , M .Ehsan ,O. Elmatboly, and A. Homaifar.2007 IEEE,39th North American power symposium (NAPS 2007).

This paper presents the application of a fuzzy logic controlled static compensator (STATCOM) to improve the transient stability of the power system. The fuzzy logic controller is used to overcome the problems generated by different uncertainties existing in power system when designing electromechanical oscillation damping controllers. Generator speed and its derivative are used to design the controllers.

Stabilization of wind Farms Connected with Multi Machine Power System by Using STATCOM.
S.M. Muyeen , student member ,IEEE, M.H .Ali , member, IEEE , R.takahashi , T. Murata, and J Tamura , member, IEEE Paper ID 152,Power tech 2007.

Recently voltage-source or current-source based various FACTS devices have been used for flexible power. Some of those are used also to improve transient and dynamic stability of wind power generation system (WPGS). This paper, proposes the static reactive compensator (STATCOM) based on voltage source converter (VSC) PWM wound rotor induction generator to stabilize grid connected squirrel cage wind generator system. A simple control strategy of STATCOM is adopted where only measurement of rms voltage at the wind generator terminal is needed. Fuzzy logic controller is used as the control a Methodology of STATCOM, rather than conventional PI .

III. RESEARCH OBJECTIVE

The main objective of the research work is to analyze behavior of STATCOM compensated Induction Generator based Wind Farms interconnected with Grid. In addition to this a comparative analysis work on the Fuzzy & PI controller implemented in the STACOM for wind power application is proposed. After the literature survey it has been noted that there are always the performance issues during a severe short-circuit and frequency stability after a sudden loss of generation in the power system. Due to heavy increase in power demand & reliability the integrated systems of Wind Farms & Grid are necessary Study of these interconnected systems & their behavior during dynamic & transient conditions are necessary to optimize the performance of the power system. In addition to this the implementation of the FACT's devices for the reactive power compensation of the Induction based wind generator is also a new area of interest.

IV .CONCLUSION

Literature survey done by various researchers is reviewed and it has been concluded Induction based Wind Farms needs the reactive power compensation. In addition to this due to implementation of Grid codes on Wind farms. The WPP's shall not be disconnected from the grid during a grid fault. They must rather be operated in such a way as to provide voltage back-up to the grid. Hence the use of FACT's devices for reactive power compensation is a new area of development after carrying out the simulation for the various fault conditions with PI & Fuzzy based controller implemented in the STATCOM. It is planned to make a comparative study on the transient stability & speed of response of both the schemes.

Based on the results the conclusion shall be drawn on the superiority of the controllers for the wind power application.

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