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Power Quality Improvement of Grid Connected Wind Energy System: A Review

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Abstract: As a promising renewable alternative, the wind power is one of the significant source of generation. In this paper, the importance of renewable energy source i.e. wind energy is being explained. There are many power quality issues pertaining when wind energy is connected to the grid. For example voltage sag, swells, harmonics, flicker etc. Inorder to mitigate these issues, various techniques have been explained in the paper like association of N-Aerogenerators with permanent Magnetic Synchronous Generator (PMSG), UPQC, Vector Control Strategy, IPQC, STATCOM, Active Power Filter etc. From the papers it can be seen that voltage variations and load current harmonics are the two critical issues responsible for deterioration of Power Quality.

Keywords: Wind Energy, Aerogenerators, PMSG, UPQC.

INTRODUCTION

In recent years, there has been an increased emphasis on, and concern for, the quality of power delivered to factories, commercial establishments and residences. Now-a-days, our technological world has become completely dependent upon the continuos availability of electrical power. In most of the countries the electrical power is made available via nationwide grids interconnecting several generating stations to the loads. The grid must supply the basic power demands of residential, lighting, industrial, financial, commercial, medical organizations and critical supply to the governmental. Restructuring of the utilities has complicated the power quality problems. In the restructured power market, government gives some permission to the power sector companies to invest in the generation, transmission and distribution of the electricity. And also gives a chance to the customers for selection of their electricity service provider. Due to that now the power scenario has become different. In the past, the customers define the quality of power based on the availability of power to them. But now in recent scenario, the aspect of power quality has totally changed.[1]

WIND ENERGY

With today's prominence on environmental consideration and conservation of fossil fuels, many alternative sources are being considered for employing the untapped energy sources of the sun and the earth for generation of power. These energy sources are inexhaustible and are known as Renewable energy sources. These include energy from water, wind, the sun, geothermal sources and biomass sources such as energy crops. Wind power is fast becoming one of the leading renewable energy sources worldwide. The growth of wind power conversion technology has been going on since 1970's, and the rapid development has been seen from 1990's. For more secure and reliable operation, the wind turbine generation should be more grid friendly.[2] Most of the wind farms uses fixed speed wind turbine, its performance relies on the characteristics of mechanical sub circuits, every time a gust of wind strikes the turbine, a fast and strong variation of electrical output power can be observed, as the response time of mechanical sub-circuits is in the range of 10 milliseconds. Wind energy has proved to be a clean, abundant and completely renewable source of power. It is economical to use in producing power in rural areas. Canada has still only scratched the surface of its massive wind energy potential, which currently powers the equivalent of 563,000 Canadian homes with a total capacity of 1,876 MW. There is the potential in Canada for wind energy to meet a full 20% of all its electrical energy needs, which is enough to power 17 million homes. Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth. Wind energy systems convert this kinetic energy to more useful forms of power. Wind turbines transform the energy of the wind into mechanical power, which can be converted to electric power to generate electricity. Wind turbines can be used singly or in clusters called 'wind farms'.[3] Today, wind energy generating system is connected into the power system to meet the consumers demand and to support the grid. However, the output power of wind generator is fluctuating and will effect operation of interconnected grid.[4] Grid integration issues are a challenge to the expansion of wind power in some countries.[5]

REVIEW PAPERS

A. Power quality improvement of a wind farm without adding any type of storage system

The wind power is characterized by fluctuation due to intermittent primary source, which can damage the electrical network stability because of the imbalance between production and consumption. To solve this problem, the authors have focussed on the dynamic of the wind farm made by the association of N-Aerogenerators with permanent magnetic synchronous generator (PMSG). The scope of this work is to investigate a new control strategy to ensure a balance, at each instant, between the wind farm generated power and the required one by the consumers without adding any type of storage systems. The proposed wind farm control is composed of two hierarchical structures. The first one is the global control applied to the manager wind turbine which has the responsibility to make, on the one hand, the wind farm generated power smooth and to ensure, on the other hand, the energy balance. The second one is the local control corresponding to the slaves wind turbines which are used only to produce the maximum of energy. Simulation results obtained by MATLAB/Simulink, for various wind speeds and power demands validate that the proposed technique gives smooth generation power and has better robustness than others existing methods. [6]

B. Fuzzy Controlled UPQC for Power Quality Enhancement in a DFIG Based Grid Connected Wind Power System.

The integration of wind farms with power grid leads to Power Quality (PQ) issues such as voltage sag, swell, flicker, harmonics etc. Most of the industrial and commercial loads are of non-linear type which indeed the starting place of harmonics. As 70% of PQ problems are voltage sag, which is one of the most severe disturbances to sensitive loads. Among many of custom power devices, Unified Power Quality Conditioner (UPQC) is the only device used to diminish both voltage sag and current harmonics. In this paper, the author analyses PQ problems, voltage sag and current harmonics due to the interconnection of grid connected wind turbine and also provides PQ enhancement by introducing UPQC. To improve the performance of UPQC, a novel control strategy using Fuzzy Logic Controller (FLC) is proposed which eliminates the drawback of using fixed gains in conventional PI controller. From the simulation results, by comparing controller performance, the proposed fuzzy controlled UPQC provides effective and efficient mitigation of both voltage sag and current harmonics than the conventional PI controlled UPQC, thus making the grid connected wind power system more reliable by providing good quality of power. [7]

C. Resonant controller based STATCOM used in wind farms to mitigate power quality issues.

Wind energy conversion method is cheaper compared to other conversions such as solar and tidal etc. There are many power quality issues in wind farms such as voltage sag, swell and harmonics arise due to grid, nonlinear load and three phase faults. These voltage fluctuations can be eliminated with the help of advanced reactive power compensation devices such as SVC (Static Var Compensator), STATCOM (Static Synchronous Compensator) and DVR (Dynamic Voltage Restorer). To reduce such power quality issues, it is essential to design, model and analyse the FACTS (Flexible AC Transmission line) device. In this paper, STATCOM is used as a compensating device. STATCOM is a static synchronous generator operated as a parallel connection static reactive compensator. It is capable of generating or absorbing real and reactive power. Also, the compensator performance is analysed with the help of Proportional Resonant (PR) controller device. The STATCOM is connected parallel with the transmission line. When fault occurs, it will inject or absorb the reactive power to the line through the transformer according to the voltage requirement. The whole system is simulated through MATLAB/SIMULINK application. The simulation gives the effective influence of STATCOM on the improvement of voltage profile as well as reduction of Harmonics in grid connected Wind Energy Conversion System. [8]

D. Voltage Profile Improvement of a Micro Grid System Using a DFIG Based Wind Energy Conversion System.

Recently micro grids are attracting attention of researchers due to the fact that they can serve as the best solution for the most alarming problems in power generation and distribution industry. Micro grids are capable of generating clean energy and supplying good quality power. In this work, the author have modelled a simple micro grid system and analysed which consists of two diesel generators and a DFIG based wind energy conversion system (WECS). Loads are connected at different points of the system. The system is subjected to load change and turbine torque variation of the DFIG, which deteriorates the voltage profile of the micro grid system.

By implementing a vector control strategy with reactive power compensation on the grid side converter (GSC), the voltage profile of the system is improved. The rotor side converter (RSC) of the WECS is also controlled by stator flux oriented vector control strategy for the decoupling control of the active and reactive power of the DFIG. This work proves that the renewable energy systems can eliminate or reduce the necessities of using FACTS devices in the system for performance improvement of the system. [9]

E. Improvement of Power Quality by Using Hybrid Fuzzy Controlled Based IPQC at Various Load Conditions.

This paper presents a hybrid fuzzy logic controlled based improved power quality conditioner used to counterbalance for harmonic distortion in three-phase system.

The IPQC employs a very simplest methodology for the calculation of the reference compensation current based on FFT Analysis. The presented improved power quality conditioner is able to operate in different load conditions (balanced, unbalanced, variable). Classical filters may not have adequate performance in fast varying conditions. But auto tuned active power filter gives out performance results for harmonic minimization, reactive power compensation and power factor improvement. The proposed auto tuned shunt active filter maintains the THD well within IEEE-519 standards.

The proposed methodology is extensively tested for wide range of different Loads with improved dynamic behaviour of IPQC using hybrid fuzzy logic controller. Thus, by using hybrid-fuzzy controller the transient response of power system network has been improved greatly and the dynamic response of the same has been made faster. [10]

F. Active Power Filter Based on Wind Turbine for Electric Power System Quality Improvement.

The increasing number of grid-connected non-linear loads causes more disruption problems to power grids. Indeed, these loads absorb periodic currents with different waveforms and consume reactive power which causes the emergence of harmonic distortion in the mains current and voltage levels that should be avoided. In order to solve this drawback, the author have presented a control scheme based on shunt active filter supplied by a wind turbine generator to compensate at the same time the harmonics currents and the reactive power caused by nonlinear loads.

The aim of this compensation is to provide a high voltage quality at the point of common coupling (PCC) through a proper control of wind turbine distributed generators interface converters. The system is simulated using MATLAB software and results are provided in order to show the performance of this compensation technique in terms of harmonic distortion reduction and power-factor improvement. In the simulation, results prove that the electrical network does not need to generate harmonic and reactive currents for non-linear loads and the mains current and load voltage becomes in phase which prove that the wind turbine can represent a perfect power factor corrector devices and active power filters. [11]

G. Minimum Copper Loss Control of Doubly-Fed Induction Generator for Wind Turbines.

In this paper, the authors proposes the control algorithms aimed at minimizing the copper loss of a doubly-fed induction generator in wind energy conversion system. In the system, the stator is directly connected to the grid while the rotor is connected to the grid through the back-to-back converter. Typically, both the stator and grid-side converter currents are controlled to be in-phase with the grid voltage for unity power factor in grid. However, it is not the optimal solution, considering the energy efficiency. The losses can be reduced under the condition of the minimum copper loss (MCL) operation.

The optimal set of rotor current commands is calculated from the analysis of torque and power properties. In this case, the grid side converter takes the role of the reactive power compensation for unity power factor in grid. So, the required amount of the converter current is also estimated. For the MCL operation, the proposed method manipulates the d-q rotor currents and d-axis converter current while the grid power factor, speed, and dc link voltage are simultaneously controlled. The feasibility and MCL tracking performance of the proposed control system are verified by simulations under various operating conditions. [12]

H. Power Quality Measurement and Evaluation of a Wind Farm Connected to Distribution Grid.

Wind power can bring new challenges when it is connected to the power grid. Generated power from wind energy system is always fluctuating due to the fluctuations in the wind. This paper shows a study on Power Quality (PQ) analysis of wind turbines installed in Hatay region and has been working for three years. Power quality parameters such as voltage, current, active, reactive and apparent power and harmonics are measured, analysed and evaluated taking into consideration IEEE 519-1992 standards. These parameters are continuously measured for three months. The recorded parameters are voltage and current rms values of all single phase for every 10 power frequency cycles, average values of current and voltage harmonics every 3 sec, active, reactive, and apparent power values and the power factor every second. [13]

CONCLUSION

From the above discussion, it can be seen that the wind power is characterized by fluctuation due to intermittent primary source, which can damage the electrical network stability because of the imbalance between production and consumption. It is necessary to meet the energy needs by utilizing the renewable energy sources like wind, biomass, hydro-cogeneration, etc. It is also concluded that the voltage variations and load current harmonics are the two main issues arising when the wind farm is connected to the grid. So it must be mitigated using various techniques.

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