A Review Article of Maximum Power Point Tracking Based Transient Analysis of Wind Power Plant

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Abstract **– This paper reviews and studies the state-of the-art of available maximum power point tracking (MPPT) algorithms. Due to the nature of the wind that is instantaneously changing, hence, there is only one optimal generator speed is desirable at one time that ensures the maximum energy is harvested from the available wind. Therefore, it is essential to include a controller that is able to track the maximum peak regardless of any wind speed. The available maximum power point tracking (MPPT) algorithms can be classified according to the control variable, namely with and without sensor, and also the technique used to locate the maximum peak. A comparison has been made on the performance of the selected MPPT algorithms on the basis of various speed responses and the ability to achieve the maximum energy yield. The tracking performance is performed by simulating wind energy system using MATLAB/Simulink simulation package. Besides that, a brief and critical discussion is made on the differences of available MPPT algorithms for wind energy system. Finally, a conclusion is drawn.**

Keywords- **Renewable Energy System, Doubly Fed Induction Generator (DFIG), Multilevel Converter Topologies, Power Quality (PQ), Grid Connected WIND, Grid Connected Wind, FACTS Devices.**

I. INTRODUCTION

As convention fossil fuel energy sources diminish and the environmental concern about acid deposition and global warming of world increases, renewable energy sources (solar, wind, tidal, biomass and geothermal etc) are attracting more attention as alternative energy sources [1]. These are all pollution free and one can say eco friendly. These are available at free of cost. In India, there is severe power shortage and associated power quality problems. The quality of the grid supply in some places is characterized by large voltage and frequency fluctuations, scheduled and unscheduled power cuts and load restrictions.

The increased complexity of transmission systems in the recent years has posed several challenges to maintain system stability. The power system stability may be broadly defined as the ability of power system to maintain synchronism after being subjected to some form of disturbance. The stability aspect is influenced by the dynamics of generator rotor angles and is a major concern for successful operation of power system. The stability study determines whether rotor can settle down to original or close to pre-disturbance operating conditions after transients disappear. For a transiently stable system, the rotor angle spread starts to increase up to its peak and then starts to decline. Transient stability is sometimes called as first swing stability as the instability often occurs during the first angular swing. By means of flexible and rapid control over the transmission parameters, FACTS technology facilitate better power flow control, decrease line loss and generation costs, improves stability and security of the power system. It opens up new opportunities for controlling and enhancing useable capacity of present as well as new upgraded line. A FACT is an evolving technology that boosts power transfer capability by 20 to 30 % and increases the flexibility of the system. The index per capita consumption of electricity is a measure of economic growth of a nation. The power quality and uninterrupted supply to large industrial consumers is therefore an important aspect.

A major power failure or outage may sometimes cause blackout over a large geographical area affecting quality of life severely. Moreover, extensive failures cause enormous economic losses. A promising and competitive alternative option is the usage of Flexible AC Transmission System (FACTS) controllers. The implementation of FACTS technology allows the existing networks to deliver reliable, cost effective, environmentally attractive and high quality electricity.

FACTS provide new dimensions in developing smart grids that maximizes carbon dioxide (CO_2) free generation. Smart grids receive power of all qualities from centralized or distributed sources and deliver power on demand. The evolved system would be based on advanced infrastructure and tuned to facilitate the integration of all involved. FACTS are in itself a highly useful, wellproven concept. FACTS technology is in operation at numerous locations around the world. These devices influence power flows and voltages thus providing the opportunity to enhance the security of the system in manifold ways: increase in transfer capacity, resolution of congestions by relieving overloaded lines, improvement in voltage profile, reduction of power losses and power oscillation damping.

The integration of dynamic energy storage with FACTS controllers has the potential to provide significant benefits to the supply chain. Load shedding in many cities in India due to power shortage and faults is a major problem for which there is no immediate remedy in the near future since the gap between the power demand and supply is increasing every year. In India wind and solar energy sources are available all over the year at free of cost .To meet the demand and for the sake of continuity of power supply, storing of energy is necessary. The term hybrid power system is used to describe any power system combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either[1-10].

II. LITERATURE SURVEY

The literature survey indicates that a lot of efforts are taken to improve the control performance of the wind power generation system under various conditions. The modern control system theory has achieved much great importance, nowadays; because of its great impact in performance and thereby affecting the dynamic response of wind energy conversion systems during the last two decades such as optimal control, adaptive control, and intelligent soft computing methods. Recently, Maximum Power Point Tracking (MPPT) controls have been reported in [Shi05]—[TanO4], in which the wind speeds, is estimated for MPPT or the maximum power point is determined without the need of the wind speed information.

Quincy Wang [QuiO4] proposed a work which focuses on the development of maximum wind power extraction, using hill climbing algorithms for inverter-based variable speed wind power generation systems. This algorithm has the capability of providing initial power demand, based on error driven control, searching for the maximum wind turbine power at variable wind speeds, constructing an intelligent memory, and applying the intelligent memory data to control the inverter for maximum wind power extraction, having any knowledge of either wind turbine characteristics or the measurements of mechanical quantities such as wind speed and turbine rotor speed.

FACTS Technology was invented in 1986 by N. G. Hingorani from Electric Power Research Institute (EPRI), USA. FACTS devices are broadly classified as series and shunt controllers both used to modify the natural electrical characteristics of AC power system. These controllers are based on thyristors with gate turn on devices. Series compensation such as gate turn on thyristor controlled series capacitor (GCSC), thyristor switched series capacitor (TSSC), thyristor controlled series capacitor (TCSC) and static synchronous series compensator (SSSC) modifies the transmission or distribution system parameters, while static VAR compensation (SVC) and static compensator (STATCOM) changes the equivalent impedance of the load. In both the cases, the reactive power flow through the system can be effectively controlled by FACTS controllers [1-5]. The electrical parameters such as voltage, current, power factor, impedance, real power and reactive power are interrelated. The control of one or more of these parameters are exercised through multiple open loop and/or closed loop systems to achieve the required benefits such as enhancement of transfer capability, voltage control etc. The performance analysis of these controllers at varying loading conditions namely small dynamic changes, under loads, overloads and short circuit is an important aspect. S. Heir focuses on Grid Integration of Wind Energy Conversion System using doubly fed induction generator and permanent magnet synchronous generator.

G. Hingorani and L. Gyugyi [2] focuses on the performance of different types of FACTS devices and are compared between them and their characteristics have been studied extensively to understand their importance in power system analysis. P.C.Krause describes on overview about the mathematical modelling of various machines including induction machine. It also discuss as in detail about the various reference frames and necessary transformations required for transferring the quantities from one reference frame to another. In the book Mohd.HasanAli describes on overview about the solution for power quality improvement and stabilization in a Wind Energy conversion system.

N.Mohan, T. M. Under land and W. P. Robins focuses on application of power electronics converters such as FACTS devices in improving power quality in a hybrid energy system. In 2011, N. Pandiarajan and RanganathMuthu, describes the mathematical equation of the PV cell is presented in a sequential manner. A single diode model is taken in to account and all the mathematical equation is presented step by step using the Matlab/simulink software.

In the year 2011, Ling Lu, Ping Liu describes on simulation of Photovoltaic model, and the different output characteristics with various MPPT technique. Two varieties of algorithms that is P&O MPPT algorithms and incremental conductance(IC) method describe very clearly and simulated using MATLAB. The P&O method is easier then Incremental Cond method and the hardware requirement is less in P&O method but there is some loss whereas Incremental Conductance method gives higher result than P&O but hardware requirement is more. So according proper MPPT technique may be chosen. Hybrid generation system uses more than one source, so that extra energy can be extracted from different sources at the same time which enhances the efficiency. In the working of PV /Wind hybrid system is studied with different topologies that can be used for the hybridization of more than one system and also about advantages and disadvantages of hybrid system is also briefed. Basic details of PV cell, PV module, PV array and their modelling are studied.

In 2011, C.N.Bhende, S.Mishara and S.G.Malla focuses on a stand-alone system with variable speed wind turbine having PMSG as a wind generator. The inverter output voltage maintained constant at rated value by maintaining the voltage across the capacitor to be constant. By controlling the modulation index of the common DC link voltage is maintained to be constant. The importance of permanent magnet synchronous generator in variable speed wind turbine is also analysis. In 2006, Swul-KI Kim, Eung-Sang Kim, Jong-Bo Ahn, focuses on a hybrid generation system. That is wind and solar system are connected together to form a hybrid system and after that this system is synchronize with grid for distribution purpose.

In 2006, Kobayashi.K,Matuso.nce H, and Sekine.Y describes an excellent operating point tracker of the solar-cell power supply system that explains the technique to obtain maximum electric power for every times even when the intensity of light temperature and temperature is varied. In 2012, JitendraKasera focuses on the mathematical model of a hybrid solar photovoltaic and wind energy system in MATLAB/SIMULINK. The proposed mathematical model is simple for simulating the solar photovoltaic and wind energy system coupled with a grid. In 2011, VlastimilŠantínmainly focused on the mathematical modelling of wind power plant with an additional component i.e. an asynchronous generator. The procedure for the modelling is to be described briefly, mathematical explanations and SIMULINK models for the wind power plant basic parts are given and the model of the entire system is presented.

In 2014, Jianwu Zeng, Wei Qiao, LiyanQu, Yanping Jiao proposes a new isolated multiport dc-dc converter for simultaneous power management of multiple renewable energy sources, which can be of different types and capacities. The proposed dc-dc converter only uses one controllable switch in each port to which a source is connected. Therefore, it has the advantages of simple topology and minimum number of power switches. A general topology of the proposed converter is first introduced. Its principle and operation are then analyzed.

In 2013, N. Ramesh babu, P. Arulmozhivarman, addressed in the paper reviews the modelling of Wind Energy Conversion Systems (WECS), control strategies of controllers and various Maximum Power Point Tracking (MPPT) technologies that are being proposed for efficient production of wind energy from the available resource. In 1998, Chen, Z., Spooner, E. used Grid Interface Options for Variable-Speed Permanent-Magnet Generators in which a voltage source inverter accompanied by a dcdc Converter was proposed. In 2006, Kobayashi.K, Matuso.H, and Sekine Y addressed in the paper describes on Novel solar-cell power provide system employing a multiple-input dc-dc device The utilization of a multiple dc-dc converter to mix many input power supply to produce the required amount of output voltage for the load from the ability supply have been studied.

In 2009, M. H. Haqueproposes an innovative technique for assessing the steady-state execution attributes of a Self-Excited Induction Generator (SEIG) under different working conditions. The issue is figured in an easy and uncomplicated path without experiencing long and repetitive deduction for the coefficients of an arrangement of nonlinear mathematical calculations. The figured issue is then resolved using a mathematical based “fsolve” specified in MATLAB. The adequacy of the projected technique is assessed on a 220-V, 1.5-KW induction generator for different working conditions. In 2005, R. C. Bansal focuses on the procedure of selfexcitation and voltage build-up, modelling in a Self-Excited Induction Generator during steady state and transient state condition. In 2015, B. Singh, S. S. Murthy, R. S. Reddy and P. Arora addressed in the paper focused on implementation of modified current synchronous detection method for voltage control of self-excited induction generator.

In 2014, U. K. Kalla, B. Singh and S. S. Murthy [30] focuses about implementation of a new voltage controller for a single-phase two-winding self-excited induction generator that is suitable for renewable energy applications, such as bio energy and diesel engine. The proposed voltage controller regulates the terminal voltage within ±5% at varying resistive, inductive, and dynamic loads. The proposed voltage controller uses only one shunt capacitor (Csh) controlled using back-to-back connected thyristors to vary the reactive power for voltage control of the self-excited induction generator. The power loss in this shunt capacitor (Csh) is 2 W for a 5-kW self-excited induction generator, which is much less compared to its counterparts, such as the static compensator. The proposed controller is useful for the remote applications for low power generation up to 5 kW. The proposed controller also regulates the system voltage for small variations in the prime mover speed due to its variable input mechanical power as well as during load perturbations.

In 2010, M. Rivera, J. L. Elizondo, M. E. Macias, O. M. Probst, O. M. Micheloud, J. Rodriguez, C. Rojas, A. Wilson addressed in the paper on a straight forward and intuitive Doubly Fed Induction Generator (DFIG) prophetic rotor current management. The management of an Indirect Matrix convertor (IMC) is connected with prophetic rotor current management of a DFIG to realize a smart dynamic response. Simulation results are made for constant torsion, movement speed, and for variable movement speed resembling a ten power unit generator dynamic response. Derivation and conjunction of every model equations are bestowed at the side of a delay error compensation strategy to counter the sensible implementation issue implicit distinct time management computation.

In 2013, Sasi.C and G.Mohan addressed in the paper on the fault analysis behaviour in a wind energy conversion system using DFIG Simulations on the fault is done that yield information on (i) What are the faults impact on the wind turbines and (ii) how the response of the wind turbines influences the post-fault behaviour of the power system. Here attempted has been made to compare the impacts in terms of voltages, active and reactive power, of adding wind turbines into electrical power grid. Therefore, the analysis of wind power dynamics with the DFIG wind turbines has become a very important research issue, especially during transient faults.

Ajami, Ali, RanaAlizadeh, and Mahdi Elmi et al. (2016) proposed a six switch converter which is basically based on the PMSG having MPPT capability. It works as rectifier to incorporate two variables wind turbine which is rely upon PMSG (permanent magnet synchronous generator). Maximum power point tracking (MPPT) is used in order to achieve higher efficiency. In low power applications, this approach is efficient in terms of cost. Also this proposed technique enhances its reliability, reduces its weight and also its size. MATLAB /SIMULIMK are used for its performance and results.

Raju Krishnama, S., and G. N. Pillaiet al. (2016) This paper talks about Type-2 Fuzzy Logic Controller for DFIG-Based Wind Energy Systems in Distribution System. DFIG based system is capable to tackle issues like faults, load changes and wind speed. The performance is checked by connecting the wind turbine to IEEE 34- bus test system. The real time simulations are carried out using real time digital simulator (RTDS) connected to hardware in loop (HIL) configuration to affirm the implementation of the controller.

Lee, Jinsik, Eduard Muljadi, Poul Sorensen et al. (2016) in this study, Releasable Kinetic Energy-Based Inertial Control of a DFIG Wind Power Plant has been proposed. In the wind power plant, wind turbine generators having several levels of releasable kinetic energy. This kinetic energy is due to wake effects. The change in frequency along with droop loops are implanted in doubly fed induction generator controller. The paper conclude about improvement in frequency.

Nguyen, Danvu, and Goro Fujita. et al (2015) In this study , Analysis of sensor less MPPT algorithm has been proposed .This strategy comprises of wind turbine, doubly fed induction generator and photovoltaic system .this strategy is then compared with the separate system with MPPT system.

Fateh, Fariba, Warren N. White, and Don Gruenbacher. et al. (2015) Suggested a MPPT technique based on wind turbines for doubly fed induction generator (DFIG). But in the conventional method, torque is directly related to the square of rotor speed and three control laws are used to adjust its proportionality coefficient. The first and second control law calculated the electrical torque and estimate real time values for power respectively. The third law provides the speed to rotor.

Nayanar, V., N. Kumaresan, and N. Ammasai Gounden et al.(2015) proposed a Maximum Power Point Tracking having single sensor. The algorithm for MPPT which is proposed here is not depending on any machine and wind turbine and MPPT method is available for application of mircogrid.

M. F. Elmorshedy et al. (2015) This paper portrays controlling procedure for a off grid WECS using a permanent magnet synchronous generator (PMSG). In this initially DC link voltage is controlled by duty cycle. Therefore, to convert the voltage of the DC link to the amplitude and to the required frequency of the charging voltage, a sinusoidal pulse-width modulation (SPWM) for controlling the inverter. The presented control strategy aims to regulate the load voltage in terms of magnitude and frequency in different operating conditions, including wind speed. Wind generation system under consideration he uses PMSG with a wind turbine, AC-DC, DC-DC and DC-AC converter. The control strategy is presented based in part on control of the duty cycle, Converter to convert the input variable to DC voltage, because to different operating conditions, at a suitable constant DC voltage. Therefore, a modulated sinusoidal pulse width (SPWM) UPS is used to adjust the amplitude and frequency by controlling the modulation index. A sample simulation results are obtained and analysed here.

Ms. Srushti R. Chafle*, A. Gadekar et al. (2015) This paper talks about control algorithm for MPPT used in cuk converter. The MPPT helps in deriving maximum power from photovoltaic and send it load by means of cuk converter boost up the magnitude of the voltage. The objective is to extract the maximum possible power from the photovoltaic module for this MPPT locates the point at which maximum power of module is available. The generalized algorithms are applied for MPPT which are easy to code and easy to use in model.

G. Hima Bindu and Dr. P. Nagaraju Mandadi (2014) Paper presents the comparison of wind systems based on various IG. Here three induction machines studied for the comparison are DFIG and SCIG and using a DFIG in single-sided grid connection. Then the performances of all three machines are compared. The controlling of rotor of SEF-DFIG by means of inverter.

Dalala, Zakariya M, Zaka Ullah Zahid et al. (2013) presented a small scale wind power system with a MPPT algorithm and it utilizes the dc current as concerning variable. The proposed algorithm identifies the sudden variation in the wind speed. The presented algorithm indicates the improved stability and less variation in the speed of wind condition and is implemented using a 1.5*103 Watt model hardware setup.

Jlassi, Imed, Jorge O. Estima, El Khil, SejirKhojet, Najiba Mrabet Bellaaj (2013) et al. presented Multiple Open-Circuit Faults Diagnosis in Back-to-Back Converters of PMSG Drives for Wind Turbine Systems. In this study different simulations and results using PMSG drives has been analyzed.

III. MOTIVATION BEHIND RESEARCH WORK:

Unlike the conventional energy sources, the non-conventional energy sources are clean, reliable, and abundant in nature. The environmental degradation such as pollution, global warming, and greenhouse gas emissions which are caused by conventional sources of energy and accelerated by ever-growing industrial activities throughout the world is a concern for all. The current researches, therefore, lay emphasis on harnessing renewable energy sources (RES) for generating electricity to supply power especially, to rural consumers where grid connection is not available.

IV.THE MPPT STRATEGY

Depending on the wind aerodynamic conditions, there exists an optimal operating point which may allow the extraction of maximum power from the turbine. The power captured by the wind turbine (equation (A.1)) can be substantially maximized by adjusting the coefficient Cp which represents the aerodynamic efficiency of the wind turbine and is dependent on the speed of the generator (or the speed ratio λ). It is necessary to design control strategies to maximize the power generated (thus the torque) by adjusting the speed of the turbine to a reference value regardless of the disturbances acting on the wind speed. There are different methods to adjust wind turbine at partial load following the trajectory of maximum power MPPT. Two different controllers been considered, the indirect speed controller speed (ISC) and direct speed controller (DSC). Thus, we have to control either the rotational speed of the turbine or the power of the turbine to reach this point. There are several MPPT methods in the literature: Those which are not based on the knowledge of the wind turbine characteristic (direct methods) and those which use the wind turbine characteristic (indirect methods). Direct methods usually lead to a complex control structure depending on the approach used to search for the MPPT. Indirect method, such as the one used in this work, searches for a pseudo maximum power point from the knowledge of the characteristic curve of the wind turbine to be driven. These methods move rapidly towards the optimum using simple measures and the internal mechanical-electrical converter, in other words, without the need to capture the wind speed. This process requires the constructor to perform a set of wind characterization tests (external fan) or 5 simulations of blade profile. For this reason, most of wind energy systems implementing an MPPT strategy are based on the knowledge of the turbine characteristics[10-13].

V.WIND PLANT AND MPPT TRANSIENT ANALYSIS

Wind power has been extensively developed in the last decade and might be a major alternative for electricity supply in the near future because of its plenitude, renewability, and wide distribution [1]. Among different wind turbine technologies, the DFIG wind turbines dominate the total installed wind turbine capacity. When the wind speed is between the cut-in and rated values, the rotor speed of a DFIG can be optimally adjusted to achieve the maximum wind power extraction [2]. Different MPPT control methods have been proposed for DFIG wind turbines and they mainly fall into two categories: wind speed measurement-based methods, in which the information of wind speed is obtained from sensors, such as anemometers, and sensorless methods without using wind speed measurements [3].

The TSR control and turbine power profile-based control are two commonly used wind speed measurement-based MPPT methods. In the TSR control, the rotor speed control signal is modified to follow the measured variable wind speed to maintain the TSR at its optimal value for maximum wind power extraction [4]. In the turbine power profile-based control, when the wind speed signal is obtained, the optimal power control signal will be generated from the curve of This work was supported in part by the u.s.

National Science Foundation under grant ECCS-09012IS and CAREER Award ECCS-095493S. 978-1-4799-5138-3/14/$3l.00 ©2014 IEEE optimal output power versus wind speed, which is usually provided by the wind turbine manufacturer, for MPPT control of the wind turbine. Although these two methods are easy to implement, their performance largely depends on the wind speed information provided by the anemometer, which may not be accurate. In addition, the total installation cost of the wind turbine system increases due to the use of mechanical sensors.

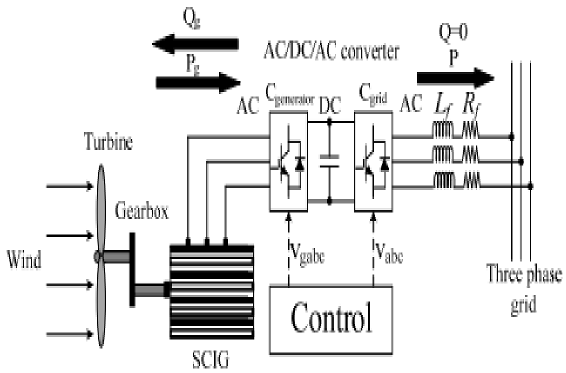

Fig (5.1) Wind turbine with a squirrel-cage induction generator.

VI. CONCLUSION

In this paper, grid integration and power quality issues of Wind System and their possible solutions available in the literature have been presented. The causes, affects, mitigation technologies featuring their topologies, highlighting the advantages of the grid integrated solar and particularly wind power systems are examined. To minimize the fluctuations and intermittent problems power electronics devices are the viable options. Further, energy storage and use of dump load and MPPT could be used for reducing the power fluctuations in PV systems. In addition to the aforesaid, the up gradation in balance of systems by incorporating the new materials and storage elements could reduce the problems associated with grid integration. The cost effective solutions of custom power devices and FACTS devices are highlighted to give an insight to the scope of research in low and medium level voltage networks and for 1Ø and 3Ø grids technologies.

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