ISSN (Online) : 2319 – 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization, Volume 3, Special Issue 1, February 2014

International Conference on Engineering Technology and Science-(ICETS'14)

On 10th & 11th February Organized by

Department of CIVIL, CSE, ECE, EEE, MECHNICAL Engg. and S&H of Muthayammal College of Engineering, Rasipuram, Tamilnadu, India

# Design and Development of MPPT for Wind Electrical Power System under Variable Speed Generation Using Fuzzy Logic

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**Abstract—This paper proposes an improved maximum power point tracking (MPPT) method for Wind system using a fuzzy with PLL algorithm. The main advantage of the method is the reduction of the steady state oscillation (to practically zero) once the maximum power point (MPP) is located. Furthermore, the proposed method has the ability to track the MPP for extreme environmental condition, e.g. large fluctuations of isolation and partial shading condition. The algorithm is simple and can be computed very rapidly. To evaluate the effectiveness of the proposed method, MATLAB simulations are carried out under very challenging conditions, namely step changes in irradiance, step changes in load and partial shading of wind array. The proposed method in simulation shows it is efficient than the conventional controllers in terms of achieving maximum wind power generation effectively with steady state output compared to other conventional controllers.**

**Keywords— Maximum Power Point Tracking, Fuzzy Logic Controller, Phase Locked Loop, Wind Energy Conversion.**

## I. INTRODUCTION

Wind Energy Conversion Systems (WECS) have been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources [1]. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. The amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the Maximum Power Point Tracking (MPPT) controller of the WECS control system irrespective of the type of generator used [2]. This study provides a review of previous MPPT controllers used for extracting maximum power and the proposed method Fuzzy Phase Locked Loop (PLL) controller with Space Vector Pulse Width Modulation (SVPWM) for maximum power point tracking. The existing controllers using Tip Speed Ratio (TSR) control, Power Signal Feedback (PSF) control And Hill-Climb Search (HCS) control to obtain maximum power point tracking [3].

The Fig.1 shows the basic flow of wind power generation. Wind turbine power is used to convert kinetic energy into electrical energy through the use of a generator. As wind conditions vary, the electrical energy created from the generator needs to be converted for usability. A rectifier, inverter, transformer and filter are needed within the wind turbine for utility-grade AC power to be transmitted over long distances [4].

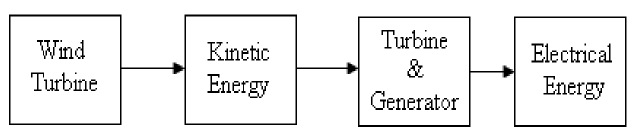


Fig.1 Basic Flow of Wind Power Generation

Wind energy can be harnessed by a wind energy conversion system, composed of wind turbine blades, an electric generator, a power electronic converter and the corresponding control system. The Fig.2 shows the block diagram of basic components of WECS.

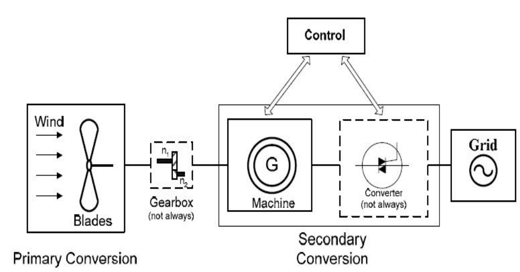


Fig.2 Block Diagram of A WECS

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There are different WECS configurations based on using synchronous or asynchronous machines and stall-regulated or pitch regulated systems [5]. However, the functional objective of these systems is the same: converting the wind kinetic energy into electric power and injecting this electric power into a utility grid or to the load.

## II. Existing Methods

### A. TIP Speed Ratio

The TSR control method regulates the rotational speed of the generator in order to maintain the TSR to an optimum value and the power extracted is maximum level. This method requires both the wind speed and the turbine speed to be measured or estimated in addition to requiring the knowledge of optimum TSR of the turbine in order for the system to be able to extract maximum possible power [6].

### B. Power Signal Feedback

In PSF control, it is required to have the knowledge of the wind turbine's maximum power curve, and track this curve through its control mechanisms. The maximum power curves need to be obtained via simulations or off line experiment on individual wind turbines. In this method, reference power is generated either using a recorded maximum power curve or using the mechanical power equation of the wind turbine where wind speed or the rotor speed is used and the maximum power is obtained [7-9].

### C. Hill Climb Searching (HCS)

The HCS control algorithm continuously searches for the peak power of the wind turbine. It can overcome some of the common problems normally associated with the other two methods [10]. The tracking algorithm, depending upon the location of the operating point and relation between the changes in power and speed, computes the desired optimum signal in order to drive the system to the point of maximum power.

## III. Development of A Grid Connected Wind Generation System With Modified PLL Structure

The Fig.3 represents the block diagram of the proposed system. The PMSG acts as the wind generator and the generated wind voltage and current values are measured by three phase voltage and current measurement. The generated Alternating Current (AC) cannot be directly given to the load. The AC is converted to Direct Current (DC). The DC is converted to AC by using IGBT and maximum power optimization is obtained. The AC input from the wind generator is applied to fuzzy controller. Fuzzy control gives continuous error signal to Space Vector Pulse Width Modulation (SVPWM) control until it reaches 50Hz with the use of Phase Locked Loop (PLL).

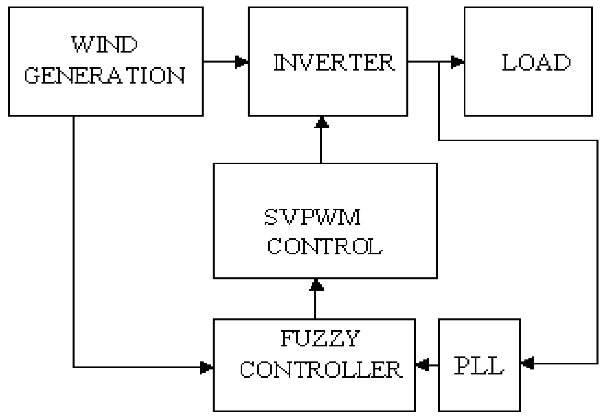


Fig.3. Block Diagram of Proposed System

## IV. Simulation Model

MATLAB/Simulink model is used to simulate the proposed model. The Fig.4 represents the simulation diagram of proposed system. This proposal proposes an improved maximum power point tracking method for wind system using a modified Fuzzy algorithm with PLL. The main advantage of the method is the reduction of the steady state oscillation and maximum power is obtained at different environmental conditions. The voltage source inverter is driven by a space vector pulse width modulation. The effectiveness of the proposed method is evaluated with MATLAB simulations. The single phase synchronous machine acts as a load and connected with the circuit. The proposed method output in simulation shows it is efficient than the conventional controllers in terms of maximum power point tracking with steady state condition.

Fig.5 represents the block diagram of wind generation block. The wind generation block consists of rotor blade measurement, speed measurement, permanent magnet synchronous generator and input voltage current measurement scope. Permanent magnet synchronous generator runs the speed of below synchronous speed it act as a motor it takes supply from the grid. PMSG runs at the above synchronous speed it act as a generator and its produces the electrical energy to the grid.

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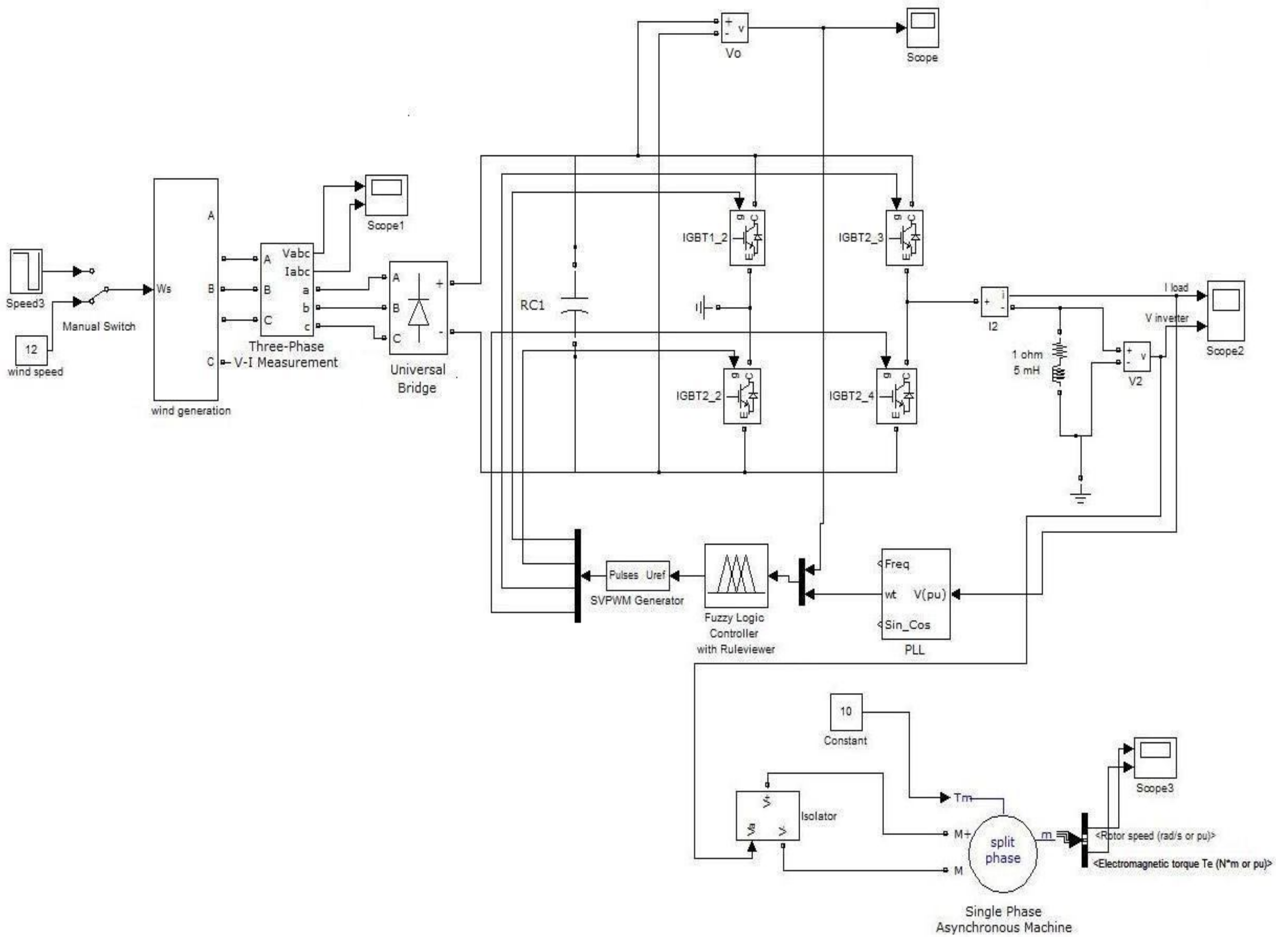


Fig.4 Simulation Diagram of the Proposed System

*A.* Universal Bridge

The universal bridge inverter is an electrical power converter that changes alternating current to direct current. The generated AC cannot be given to the load directly so the AC converted to DC. With the help of transformers, switching and control circuits converted alternating current can be converted to any required voltage and frequency. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. The Universal Bridge block implements a universal three phase power converter that consists of up to six power switches connected in a bridge configuration. The universal bridge block is the basic block for building two levels Voltage Sourced Converters (VSC).

*B.* MPPT Algorithm (Buck Boost Operation Using IGBT'S)

The IGBT'S used as the DC to AC converter and act as Buck Boost converter. The output voltage is adjustable based on the duty cycle of the switching transistor.

*C.* Phase Locked Loop Structure

The phase angle of the voltage on any grid connected generation system such as in wind farms is very important and must be known. To estimate the phase angle of voltage, a PLL is commonly used. The PLL algorithms have three main sections, namely a phase detector, filter and voltage controlled oscillator. Most

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PLL structures usually differ on the PD. The instantaneous reactive power theory was originally proposed for three phase applications. The PLL output is tuned using Fuzzy logic. The PLL maintains the frequency as 50Hz. The generated voltage can be connected to the grid or to the load directly. Fuzzy logic is a form of many valued logic and deals with reasoning that is approximate rather than fixed and exact. The binary sets have two valued logic true or false. The Fuzzy logic values have the truth value range is 0 to 1. The voltage and current value measured in the three phase voltage and current measurement scope.

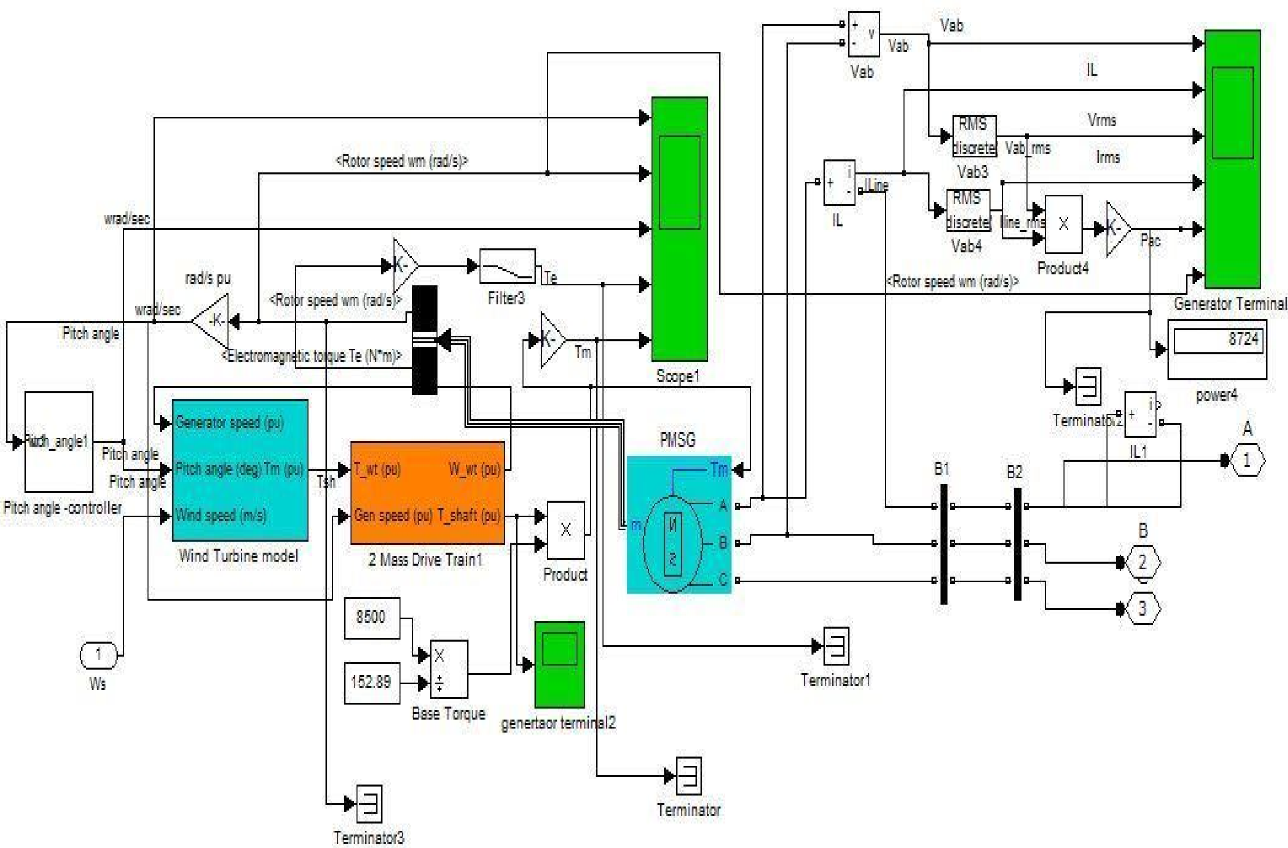


Fig.5 Simulink Diagram of Wind Generation Block

## V. RESULTS AND DISCUSSION

The input voltage and current measurement value is shown in Fig.6. The Fig.7 represents the output waveform corresponding to the input values. The waveform contains maximum voltage deviations.

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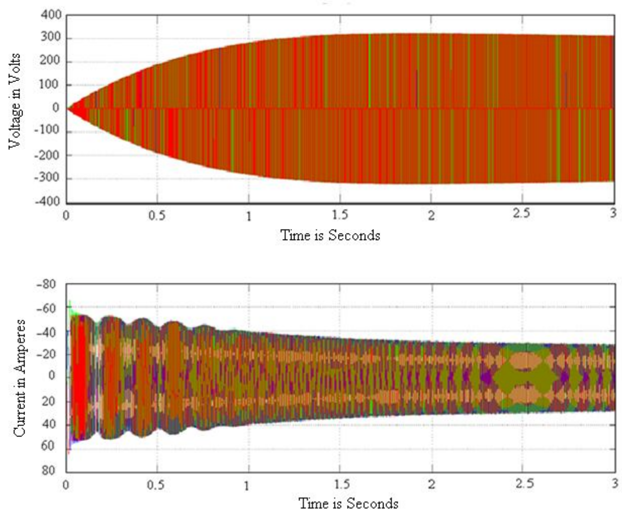


Fig.6 Input Voltage and Current Waveform

The FFT analysis of harmonics level input is shown in Fig.8. The FFT analysis generated after getting wind power as an input. The current and voltage waveforms contain disturbing harmonics. The Total Harmonic Distortion (THD) used to mention the harmonic level. The THD value is 38.62%.

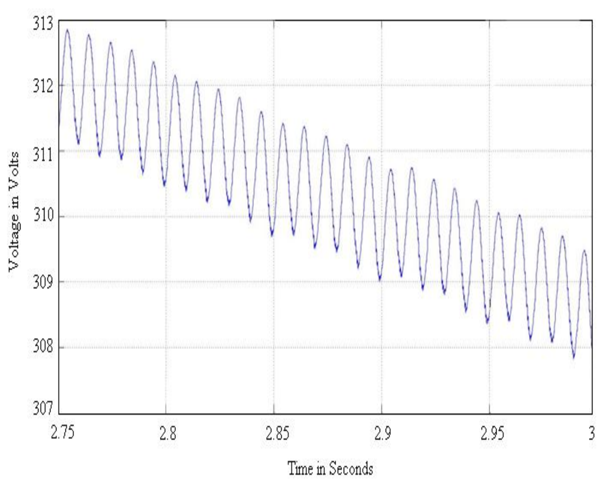


Fig.8 FFT Analysis of Harmonics Level in Input

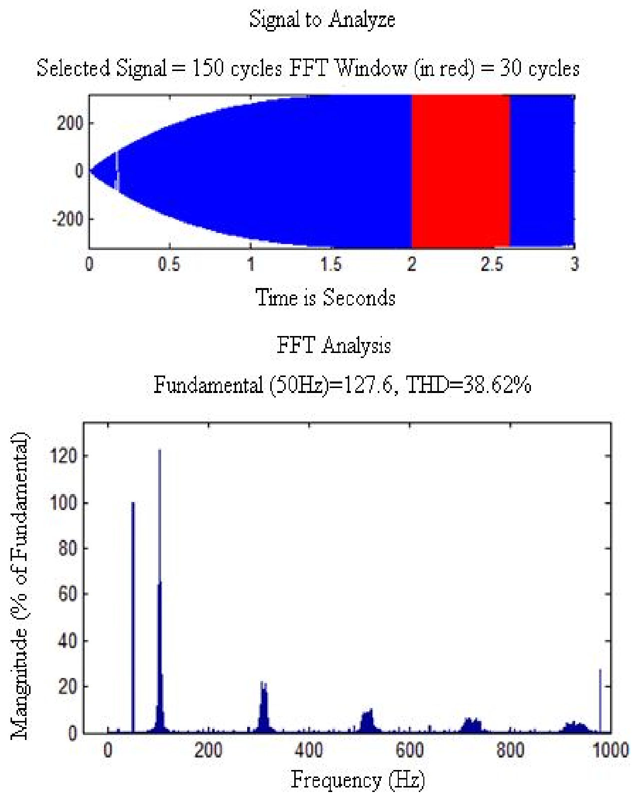


Fig.8 Output Waveform for Input Values

Fig.9 shows the output voltage and current waveforms using fuzzy logic and PLL with MPPT. The output voltage and current waveforms generated with PLL. The harmonic levels are reduced and maximum power is obtained.

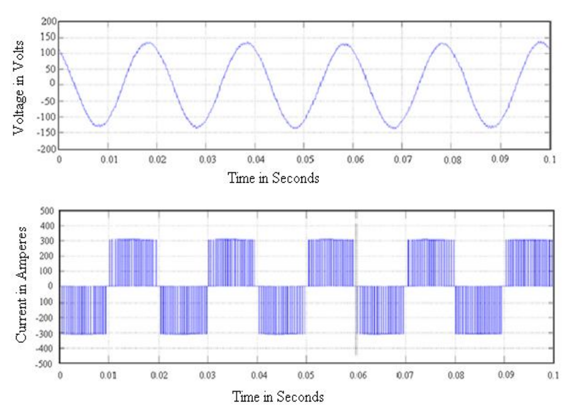

Fig.9 Output Voltage and Current Waveforms using Fuzzy Logic and PLL with MPPT

The Fig.10 represents the FFT analysis of in the output. The output is with maximum power. The THD level is 0.52%. The output is compared with the previous results without the feedback of PLL. The proposed model reduces the THD value.

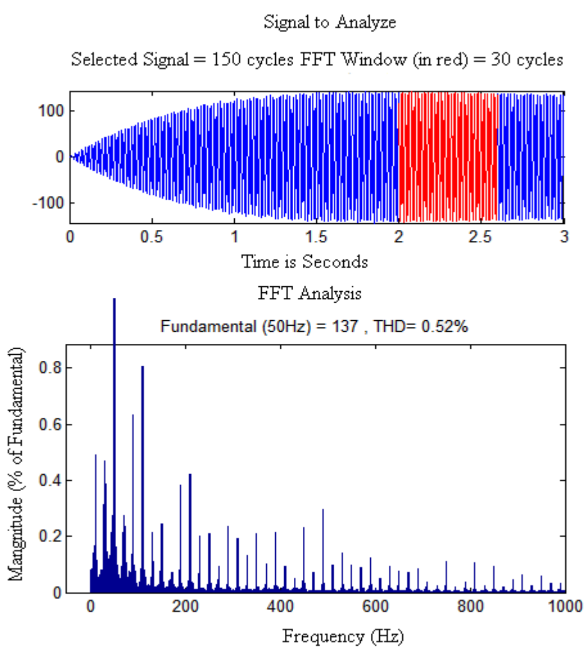


Fig.10 FFT Analysis of Harmonics Level in Output

## VI. CONCLUSION

The design, simulation of WECS with maximum power point tracking with PLL and fuzzy controller is proposed. Synchronization with the main grid are connecting the output with the load is achieved using a PLL algorithm. The MPPT algorithm shows the ability to find the MPP point on any operating point. The modified PLL algorithm has a lock capacity of about 32–50 ms for sudden changes in phase and frequency, which is considered a good response. It also showed the capacity to lock to the fundamental frequency under heavily distorted signals 38% THD and the PLL structure represents a practical solution for grid connected or load connected WECS with a THD level of 0.52%.

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