ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Grid Connected Wind Energy System Using Perturb and Observe Method

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Abstract:

A wind-generator (WG) maximum-power-point tracking (MPPT) system is presented, consisting of a high efficiency buck-type dc/dc converter and microcontroller-based control units running the MPPT function. The advantages of the proposed MPPT method are that no knowledge of the WG optimal power characteristic or measurement of the wind speed is required and the WG operates at a variable speed. Thus, the system features higher reliability, lower complexity and cost, and less mechanical stress of the WG. Experimental results of the proposed system indicate near optimal WG output power, increased by 11%–50% compared to a WG directly connected via a rectifier to the battery bank. Thus, better exploitation of the available wind energy is achieved, especially under low wind speeds.

Index Terms:

Buck converter, maximum power point tracking (MPPT), microcontroller, variable speed, wind generator (WG).

INTRODUCTION:

Electrical energy is produced in large scale using conventional methods utilizing the non-renewable resources like coal, diesel, gas etc. Due to increasing population, electrical energy is being extensively used and reserves of these non-renewable sources are getting depleted. As a solution, the world is now looking towards development of efficient technologies which utilizes renewable sources and produces electricity. Economically, it is not easy to expand a power system in terms of generation if the demand is increasing and it is a better idea to supply the excess demand using the distributed energy produced from the renewable like the wind energy [8].

Energy which is generated at places where these renewable are obtained, integrated to the power system grid to supply the excess demands and reduce the burden on the grid. Also, these distributed generations can be used to supply the loads which are near by the wind farm site. Wind energy is the natural form of energy which is available freely in the atmosphere. It can be used by converting it into mechanical and electrical energy at locations where it is available. The system which is used to convert the wind energy into electrical energy is Wind Energy Conversion System [5].

Wind Energy Conversion System:

The generic block diagram of a wind energy conversion system (WECS)[4] is shown in Fig. 1. It consists of a wind turbine, generator and power electronic converters to interface the energy converted from the wind to local load or grid.

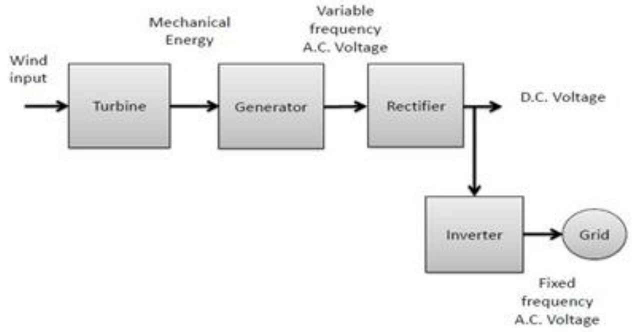

Figure 1: Block diagram of Wind Energy Conversion System

Power in wind available for the turbine rotor, i.e. energy per unit time can be expressed as

$$P = \frac{1}{2}\frac{dm}{dt}(V_w)^2 \qquad (2.3)$$

$$P = \frac{1}{2}\rho_a A (V_w)^3 \qquad (2.4)$$

Where $V_w = V^*\cos\theta$

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$$\theta = -0.00017327V^5 + 0.0085008V^4 - 0.12034V^3 + 0.4501V^2 + 1.0592V + 0.3892$$

V is wind speed in (m/s), θ is furl angle in degrees

Air density is affected by several factors like temperature, atmospheric pressure, elevation etc. For a given elevation Z and temperature T, air density can be expressed as

$$\rho_a = \frac{353.049}{T} e^{(-0.034Z/T)} \quad (2.4)$$

Therefore air density decreases with temperature and elevation.

Power output of the turbine rotor is given as [8]

$$P_T = \frac{1}{2} C_p \rho_a A (V_w)^3 \quad (2.5)$$

Similarly, torque developed by the machine can be expressed as,

$$T_T = \frac{1}{2} C_t \rho_a A (V_w)^2 R \quad (2.6)$$

Where C_P and C_t are power and torque coefficients and R is radius of turbine.

Tip Speed Ratio (TSR) is the ratio of turbine tip speed to wind speed and can be expressed as

$$\lambda = \frac{R * \omega}{(Vw)} \quad (2.7)$$

Relation between both coefficients can be expressed in terms of TSR as

$$\frac{Cp}{Ct} = \lambda \quad (2.8)$$

$$Cp = 0.517 \left(\frac{116}{\lambda i} - 0.4\beta - 5\right) e^{\left(-\frac{21}{\lambda i}\right)} + 0.0068\,\lambda \quad (2.9)$$

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{(\beta * \beta * \beta) + 1} \quad (2.10)$$

Wind Turbine Emulator:

A Wind Turbine emulator (WTE) is a piece of hardware which is used to mimic the characteristics of a real wind turbine [3]. The main idea behind the development of WTE is to establish a testing platform where the study on WECS can be carried out without depending on natural wind resource. It helps in the development of new maximum power point techniques.

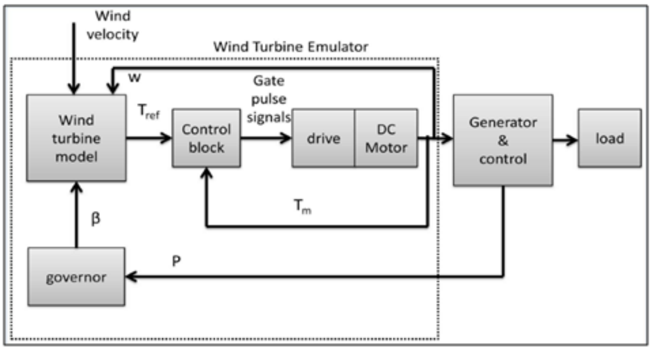

Figure 2: Generic Block Diagram of Wind Turbine Emulator

Maximum Power Point Tracking (MPPT):

Since, the energy available from wind is for free and environment friendly, we always try to extract maximum power from it by using conversion systems [1, 2]. In order to operate the system at maximum conversion efficiency, conversion strategies should analyze the wind magnitudes and adjust the rotor speed by using mechanical or power electronic controlling schemes. Since wind energy varies rapidly, we have to capture as much energy as possible in minimum time. Hence Maximum Power Point Tracking Algorithms (MPPT) should be used.

Perturbation and Observation (P & O) control:

P & O method or Hill Climb Search (HCS) method is used to find the local optimum value of a given function. It is widely used in WECS for extracting maximum energy from wind [6]. This technique is based on perturbing a control variable and observing the changes in the targeted variable until the slope becomes zero. We can even perturb duty cycle of the DC-DC converter, output DC current or Input DC voltage etc. Sensors are not needed in electrical power measurements and hence they are reliable and of low cost. Advantage of this control is we do not need to have the prior knowledge of the turbine characteristics. If the operating point is left to the optimum point, then the control should act such that the operating point moves towards right and vice-versa.

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Finally it should reach the optimum point. Since, wind is not steady, the characteristic of turbine will always vary and hence the MPPT control should also act quickly [7].

Simulation of WECS:

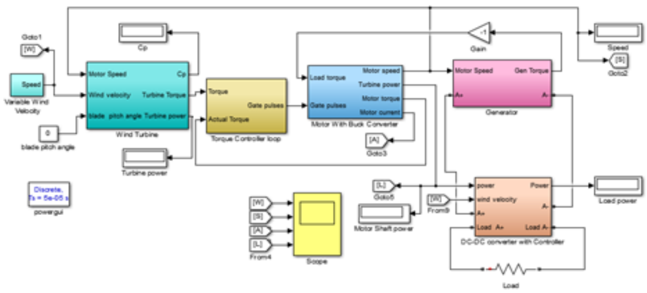

Figure 3: Matlab/Simulink Model of Wind Energy Conversion System with MPPT Implementation

Tuning of digital PI controller gains is made using Ziegler- Nichols method for good initial guess and after several trial and errors a suitable fine-tuned set was determined. The speed and motor power graphs for without implementation of MPPT at [4] constant wind velocity 7 m/s

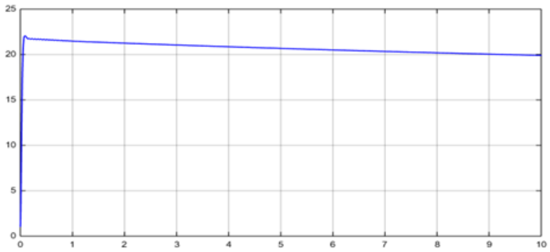

Figure 4: Speed of the DC motor without implementation of MPPT

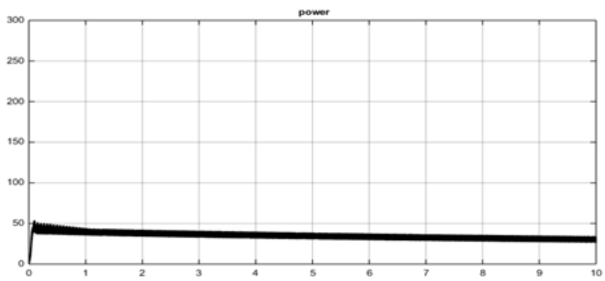

Figure 5: DC motor power output without implementation of MPPT

The speed and motor power graphs for with implementation of MPPT at constant wind velocity 7 m/s

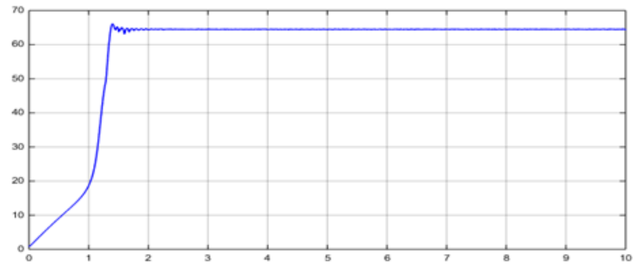

Figure 6: Speed of the DC motor with implementation of MPPT

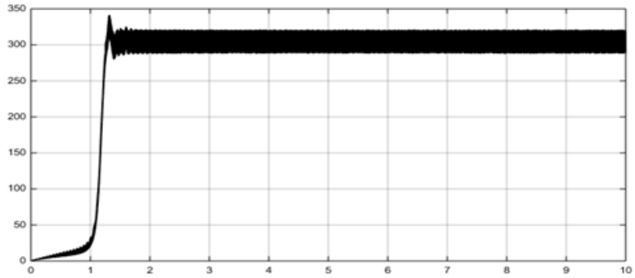

Figure 7: DC motor power output with implementation of MPPT

The speed and motor power graphs for with implementation of MPPT with variable wind velocity (Wind velocity input is made to vary from 7 m/s to 6 m/s after 5 seconds).

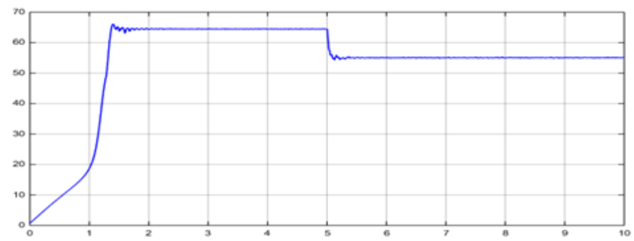

Figure 8: Speed variations of the DC motor with wind velocity variations after implementation of MPPT

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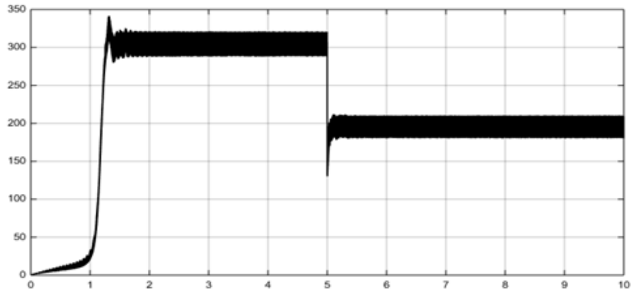

Figure 9: DC motor power output variation with wind velocity variations after implementation of MPPT

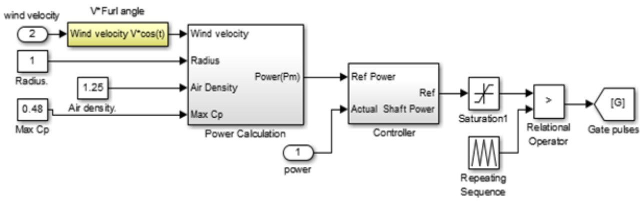

Figure 10 Simulation diagram of Maximum Power Controller

cv

Conclusion:

A thorough literature survey is done in the area of wind turbine emulation and maximum power point tracking. Simulation of the Wind Energy Conversion System model is developed in MATLAB/Simulink by emulating the wind turbine using DC Machine. The set-up is responding to the varying wind velocities like an actual wind turbine. Maximum power point tracking algorithm was successfully implemented and from the analysis of the results, it can be observed that the power output of the wind turbine emulator increases when maximum power point control was implemented. Speed of the set-up adjusts to the optimum point thereby increasing the power output. Considerable output increasing can be observed at higher wind velocities. The set-up can be used for further research on new maximum power point tracking algorithms and effective power conversions.

References:

[1] E. Koutroulis and K. Kalaitzakis,\Design of a maximum power tracking system for wind-energy-conversion applications", IEEE Trans. on Ind. Electron, vol. 53, Apr. 2006.

[2] Ruihong Yu, Yannqin Li and Jianxian Cai, \Maximum Power Point Tracking from a Wind Turbine Emulator Using a DC-DC Converter Controlled”, International journal of control and Automation, Vol. 7, No.1 (2014), pp.117-128.

[3] Jakeer Hussain, Mahesh K. Mishra,\ Design and Development of Real-Time Small-Scale Wind Turbine Simulator” 2014 IEEE.

[4] Q. Wang and L.-C. Chang, \An intelligent maximum power extraction algorithm for inverter-based variable speed wind turbine systems", IEEE Trans. On Power Electron, vol. 19, pp. 1242-1249, Sep. 2004.

[5] T. Hardy and W. Jewell, \Emulation of a 1.5MW wind turbine with a DC motor", IEEE, PES General Meeting, pp. 1-8, Jul. 2011.

[6] G. Moor and H. Beukes, \Power point trackers for wind turbines", IEEE PESC, pp. 2044-2049, 2004.

[7] T. Nakamura, S. Morimoto, M. Sanada, and Y. Takeda, \Optimum control of ipmsg for wind generation system", Power Conversion Conf. (PCC), vol. 3, pp 1435-1440, 2002.

[8] R. Datta and V.-T. Ranganathan,\A method of tracking the peak power points for a variable speed wind energy conversion system", IEEE Trans on Energy Conversion, vol. 18, pp. 163-168, Mar. 2003.