International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
©2017 INPRESSCO®, All Rights Reserved
Available at http://inpressco.com/category/ijcet

*Research Article*

# Control of Variable Pitch and Variable Speed Direct-Drive Wind Turbines in Weak Grid Systems with active Power Balance

**Shikha Mishra*, Pankaj Jain and Mukesh Pandey**

School of Energy & Environment Management, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, India

Received 01 May 2017, Accepted 14 July 2017, Available online 15 July 2017, **Vol.7, No.4 (Aug 2017)**

***Abstract***

*In this paper the sustainability of a 2 KW hybrid of wind and battery arrangement is examined for meeting the necessities of a stand-alone dc load. This development is convenient with the development of control schemes for small level wind turbine that requires relatively low power. As wind flow is erratic in nature, hence to make sure incessant make available of power appropriate storage device as battery is used as backup. A charge controller for battery bank supported turbine most power point tracking and battery state of charge is developed to make sure controlled charging and discharging the battery. The mechanical safety is secure by means of pitch control method. The automatic protection of the WECS is also secure by means of pitch management technique. Each the control schemes are integrated and effectualness is valid by testing it with numerous Load and wind profiles in MATLAB/SIMULINK.*

***Keywords***: *Permanent-magnet generators, wind energy, wind turbine, weak grid*

## 1. Introduction

Wind results from air to motion. Air in motion arises from a pressure gradient. Wind is basically caused by the solar energy irradiating the earth. This is why wind utilization is considered as a part of solar technology. Wind power is the use of air flow through wind turbines to mechanically power generators for electricity. Wind power is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water and uses little land. The net effects on the environment are far less problematic than those of non-renewable power sources. Wind is the movement of air across the surface of earth, affected by areas of high pressure of low pressure. Wind energy conversion devices are commonly known as wind turbines because they convert the energy of the wind stream into energy of rotation.

The wind flow is inconsistent in nature thus; a WECS is integrated with the load by means that of an ac-dc-dc converter to discourage from voltage flicker and harmonic generation. The control scheme for a separate hybrid wind–battery system includes the charge controller circuit for battery banks and pitch control logic to create certain WT operation contained by the rated value. The control logic makes sure efficient control of the WECS alongside all possible disturbances. The wind speediness is one of the important factors in determining how much power can be extracted from the wind. The power accessible from a WECS is very unpredictable in nature. The control logic execute in the hybrid set up consist of the charge control of battery depository with MPPT and pitch control of the WT for making sure electrical and mechanical protection. The hybrid Wind battery system all by the side of its control logic is developed in MATLAB/SIMULINK.

## 2. Theory

Due to a moderately low cost of electricity production wind energy is well thought-out to be one of the potential sources of renewable energy for the prospect. But the character of wind is stochastic. Therefore specific testing is performed in laboratory to develop proficient control strategy for wind energy conversion system (WECS). These days, many stand-alone loads are powered by renewable source of energy.

We know that the wind flow is unpredictable in nature. Hence, a WECS is integrated with the load by means of ac-dc-dc converter not to be affected from voltage flicker and harmonic generation. The control method for a hybrid wind- battery system includes the charge controller circuit for battery banks and pitch control logic to make certain WT operations inside the rated value. The control logic makes sure effective control of the WECS alongside all possible disturbances. Here we have following 2 types of control strategies.

*Corresponding author's ORCID ID: 0000-0002-8544-2662

*2.1 Pitch Control Mechanism*

If the wind turbine is allowed to operate over the complete range of wind speed while without execution of any control mechanism, angular speed of shaft exceeds its rated value which can lead to damage of blades. Therefore it's essential to manage the speed and power at wind speeds above the rated wind speed. This can be achieved by changing the pitch angle of blade of the WT. Such a mechanism is referred to as Pitch control mechanism.

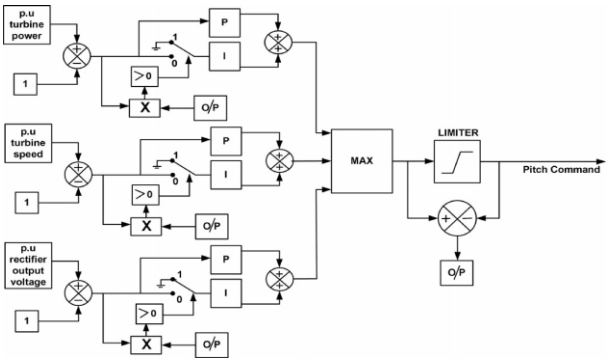


**Fig.1** Pitch Control Scheme

*2.2 Maximum Power Point Tracking (P &O)*

A MPPT or maximum power tracker is an electronic dc to dc converter that optimizes the match b/w wind generator and the battery bank/ utility grid. To put it simply, they convert a higher voltage dc o/p from wind generators down to the lower voltage needed to charge batteries. This dc converter takes dc input from wind generator, changes into AC and converting it back to a different DC voltage and current to exactly match the Wind generator to charge the battery. Maximum Power Point Tracking is a technique used with wind turbine system to maximize power o/p. In our discussion we are using P &O algorithm (Perturbation and Observation). This method is also called Hill – climbing Method. It is the most commonly used MPPT scheme due to its ease of implementation. This method results in top – level efficiency. This technique has been extensively used in power processing of batteries.

*2.3 DC- DC Bidirectional Converter*

Full-length Battery storage system is important for a stand –alone wind energy supply system to sustain the balance among the generated power from wind turbine and requisite load power in the course of charge/discharge energy to/ from this storage system .The batteries bank is linked to the DC-link voltage in the course of a DC-DC bidirectional buck-boost converter. The management of this converter will sustain the DC-link voltage at constant value as a reference value additionally to charge/ discharge current to/from the batteries bank according to the necessary load power. The batteries bank voltages are often kept less than the reference DC-link voltage (vdc) and thus fewer no of batteries need to be connected serial.

## 3. Method

*3.1 MPPT (P&O)*

*III.A. Definition of MPPT*

- MPPT or Maximum power point tracking is an algorithm that is included in charge controllers used for extracting maximum available power from wind generator system.
- A MPPT or maximum power point tracker is an electronic DC to DC converter that optimizes the match b/w wind generator and the battery bank / utility grid.
- MPPT is DC to DC converter which operates by taking DC i/p from wind generator, changing it back to a different DC voltage & current to exactly match the wind to generator to charge the battery.
- The technology of MPPT is employed to increase the efficiency of wind energy system as they are designed for peak power extraction also, they attempt to pull the max possible electrical power from a given wind turbine under the current wind conditions.

*III.B. Function of MPPT*

i. A maximum power point tracking (MPPT) algorithm increases the power conversion efficiency by regulating the turbine rotor speed according to actual wind speeds.
ii. It makes sure that battery discharge current is within specified limit.
iii. It also protects the buck converter from over current situation.
iv. To enhance the efficiency and economics of wind energy conversion systems (WECS).

*III.C. Classification of MPPT Schemes for WECS*

Basically, there are three types of MPPT algorithms, namely

i. TSR Control (Tip Speed Ratio).
ii. P&O (Hill- Climbing Search).
iii. OTC (Optimal Torque Control)

*III.D. P& O (Perturbation & Observation)*

In this control scheme we use P&O method. In any MPPT technique two inputs are taken one is voltage (v) and second one is current (i). Perturbation variable as dc current is used in our proposed scheme.

The perturbation and observation (P&O), or hill-climb searching (HCS) method is a mathematical optimization technique used to search for the local optimum point of a given function. It is widely used in wind energy systems to determine the optimal operating point that will maximize the extracted

energy. This method is based on perturbing a control variable in small step-size and observing the resulting changes in the target function until the slope becomes zero. P&O control adjusts the turbine speed toward the MPP, according to the result of comparison between successive wind turbine generator output power measurements. It is especially suitable for small-scale WECSs, as an anemometer is not required and the system knowledge is not needed.

The Perturbation is opted as one of following conditions.

i. Perturb the rotational speed and observed the mechanical power.
ii. Monitor the output power of generator and perturb the inverter input voltage
iii. Monitor the output power of the generator and perturbed the converter variables i.e Duty cycle, output current, input voltage.

To improve the efficiency and the accuracy of the conventional P&O method, modified variable step-size algorithms have been proposed. In adaptive step-size methods, the step-size is automatically updated according to the operating point. If the system is working on a certain point that is far from the peak, the step-size should be increased to speed up the tracking process. Conversely, the action is reversed to decrease the step-size when the operating point nears the MPP.

The step-size is continually decreased until it approaches zero in order to drive the operating point to settle down exactly at the peak point. This working principle reduces the oscillations that occur in the conventional P&O method, accelerates the speed to reach the maximum, and lowers the time for tracking.

*III.E. Advantages of P& O*

- Ease of implementation
- Top level efficiency
- Extensively used
- Simple method
- Does not require prior knowledge about turbine, generator & wind characteristics.

The MPPT algorithm proposed to track the MPP by perpetually adjusting the inductor current to reach the MPP. The dc-link voltage is not controlled. Thus, it will be monitored and the natural comportment of the dc voltage during wind speed change will be acclimating to enhance the tracking speed of the algorithm.

The algorithm works in two distinct modes: The normal P&O mode under slow wind fluctuation conditions in which an adaptive step size is employed with the power increment utilized as a scaling variable.

The second mode is the predictive mode under sudden wind speed change conditions; this mode is responsible for bringing the operating point to the vicinity of the MPP during expeditious wind speed change, and it will avail obviate the generator from stalling by rapidly adjusting the generator torque in replication to sudden drops in wind speed.

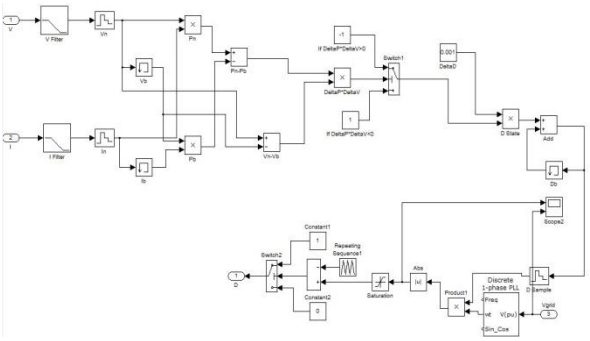

**Fig. 2**: Proposed MPPT (P&O) Model

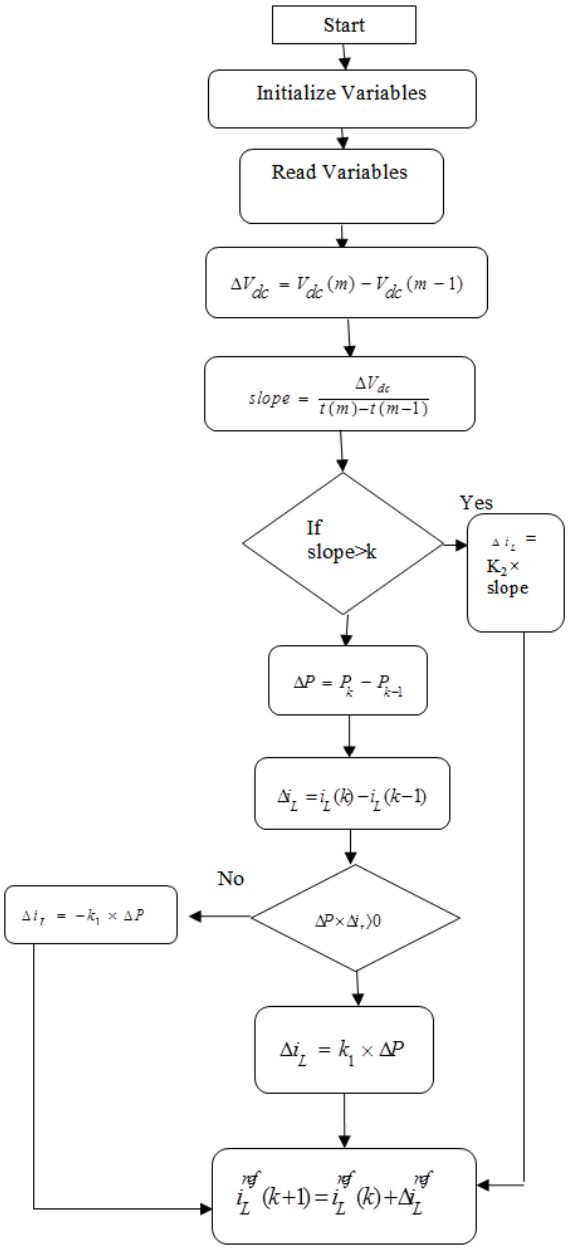


**Fig. 3**: Flow chart of the MPPT Algorithm

In this mode, the dc-link voltage slope is utilized as a scaling variable and is utilized to determine the next perturbation direction. Proposed MPPT algorithm will run as mundane adaptive step size P&O algorithm unless a wind speed change causes the system to rapidly expedite or decelerate. In this case, the system will counteract the expedition/deceleration by transmuting the reference current felicitously and moving the operating point much more proximate to the incipient MPP. Then, the algorithm will then resume normal P&O mode. This method results in a saliently conspicuous tracking speed enhancement. More importantly, the system is averted from sudden stalling during sudden wind speed reductions.

The method searches for the best possible correlation of the output rectified dc voltage and current in short time. An advanced P&O method is proposed to remove the consequence of fluctuating wind conditions. Then, the system is controlled based on this optimum relationship. The proposed MPPT technique doesn't need an anemometer or the system pre-knowledge, however has a correct and quick response to fluctuating wind speeds. MATLAB/Simulink simulation and practical results ensure the validity and performance of the proposed MPPT algorithm.

In this control scheme we use P&O method. In any MPPT technique we take two inputs one is voltage and second one is current produced from WT. We are using as a perturbation variable as dc current in our proposed scheme.

## 4. Result

Abbreviation Proposed simulation model is basically based on renewable energy. It has three parent sections. Section 1st is wind, second is MPPT and last is the battery block. In wind basic focus is on pitch angle and wind speed. This wind model basically generates power, current and voltage with reference speed. The simulation results are below in fig.

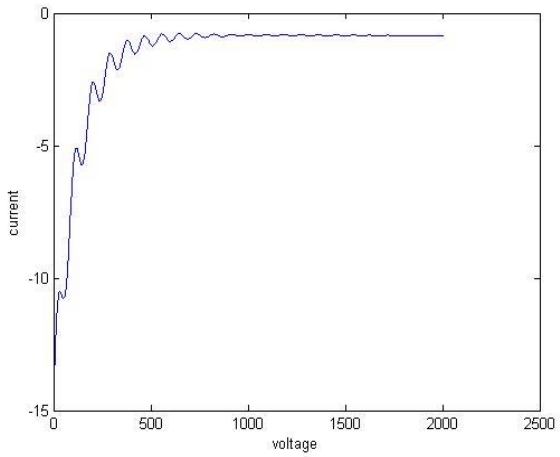


**Fig 4**: Current vs voltage graph

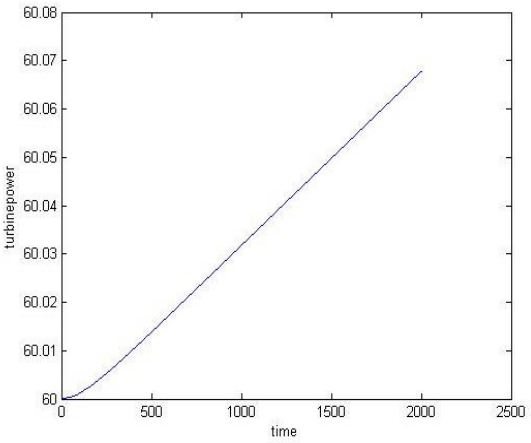


**Fig 5**: turbine power vs time graph

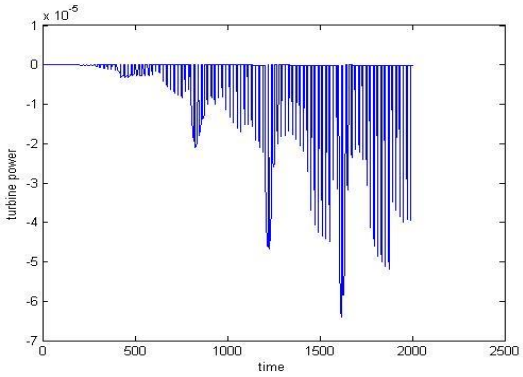


**Fig 6:** Turbine power vs time graph

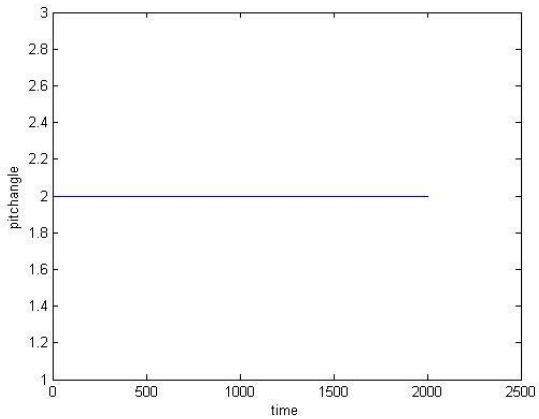


**Fig 7:** Pitch angle vs time.

## Conclusion

In this paper used P&O algorithm for MPPT in modified form which is easy to implement, simple, has high level efficiency and extensively used. Hybrid wind-battery system together with its control logic is developed in MATLAB/SIMULINK and is getting tested with wind profile. The outcome of the simulation experiments validates the improved performance of the system, provides stability, by reducing voltage flickers and harmonics. The control logic implemented in the hybrid set up is included with charge control of battery bank based on MPPT algorithm and pitch control.

## References

Xibo Yuan, Yongdong Li (2014.) Control of variable pitch and variable speed direct-drive wind turbines in weak grid systems with active power balance, The Institution of Engineering and Technology

Roberto Cárdenas and Rubén Peña (March 2004), Sensorless Vector Control of Induction Machines for Variable-Speed Wind Energy Applications, IEEE Transactions on Energy Conversion, Vol. 19, No. 1.

Muljadi, Eduard, *et al*. (2007) Effect of variable speed wind turbine generator on stability of a weak grid. IEEE Transactions on Energy Conversion 22.1: 29-36.

M´onica Chinchilla, Santiago Arnaltes, and Juan Carlos Burgos (March 2006) Control of Permanent-Magnet Generators Applied to Variable Speed Wind-Energy Systems Connected to the Grid, IEEE Transactions On Energy Conversion.

L. Ran, J.R. Bumby, P.J. Tavner (2004)Use of Turbine Inertia for Power Smoothing of Wind Turbines with a DFIG, International Conference on Harmonics and Quality of Power.

Kanellos, F.D., Hatziargyriou, N.D.( 2008) 'Control of variable speed wind turbines in islanded mode of operation', IEEE Trans. Energy Convers., 23, (2), pp. 535–543

Muljadi, E., Butterfield, C.P., Parsons, B., Ellis, A.( 2007) 'Effect of variable speed wind turbine generator on stability of a weak grid', IEEE Trans.Energy Convers., 22, (1), pp. 29–363

Bindner, H. (March 1999)'Power control for wind turbines in weak grids: concept development'. Riso national laboratory report.

Liserre, M., Cardenas, R., Molinas, M., Rodriguez, J. (2011)'Overview of multi-MW wind turbines and wind parks', IEEE Trans. Ind. Electron., 58, (4), pp. 1081–1095

Kanellos, F.D., Hatziargyriou, N.D.( 2002) 'The effect of variable-speed wind turbines on the operation of weak distribution networks', IEEE Trans.Energy Convers.