# ADAPTIVE MAXIMUM POWER POINT TRACKING CONTROL ALGORITHM FOR WIND ENERGY CONVERSION SYSTEMS

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***Abstract*— Wind energy systems are being closely studied because of its benefits as an environmentally friendly and renewable source of energy. Because of its unpredictable availability, power management concepts are essential to extract as much power as possible from the wind when it becomes available. The proposed control algorithm allows the generator to track the optimal operation points of the wind turbine system under fluctuating wind conditions and the tracking process speeds up over time. This algorithm does not require the knowledge of intangible turbine mechanical characteristics such as its power coefficient curve, power characteristic or torque characteristic. The algorithm uses its memory feature to adapt to any given wind turbine and to infer the optimum rotor speeds for wind speeds that have not occurred before.**

***This project proposes a new Maximum Power Point Tracking (MPPT) algorithm employed in Wind Energy Conversion Systems (WECS). One of the major issues discussed in the literature concerning HCS is its inefficiency in detecting the peak power when there is a change in wind ·speed. In addition, the HCS produces oscillations in delivered power once this peak is detected. A modified HCS algorithm is proposed in this project to overcome these limitations. This algorithm employs a variable duty cycle to reduce the oscillations in delivered power once the peak power is detected. The performance of the proposed algorithm was evaluated using MATLAB/SIMULINK.***

***Index Terms*— Maximum power point tracking, hill climb search algorithm, tip speed ratio algorithm, power signal feedback algorithm, single-ended primary inductor converter (SEPIC) dc-dc converter.**

## I. INTRODUCTION

The dependence on non-renewable energy sources like coal, natural gas and nuclear energy has reached such an extent that these resources have shown signs of depletion (www.renewable-energy-sources.com). This has led to a global increase in the prices of the energy harnessed from these sources (Congress of the United States Congressional Budget Office, 2006). In addition to the economic impacts, this dependence on non-renewable resources has caused serious environmental issues. For example, a single 100MW coal power plant produces approximately 25 pounds of mercury (A Greenpeace Southeast Asia Report, 2005), which can spread approximately 600 miles from the source (Greenpeace Briefing). Some of the other issues associated with utilizing these non-renewable resources are that they present a serious threat to wildlife during the various stages of harnessing the energy and the disposal of associated wastes. These concerns have encouraged research and development of renewable resources like solar, wind, hydro, tidal, and geothermal energy. These renewable energy sources are also very eco-friendly, with fewer emissions and issues related to waste disposal.

As renewable sources do not requiring and transportation, they do not threaten wild life. In addition to these direct advantages, there are many hidden economic advantages to adopting renewable energy. These include: revitalization of rural communities by making use of otherwise wasted lands; reduction in transportation costs as the fuel is available at the place of production; and stabilization of price among others. Even though renewable energy is a good substitute for conventional sources, there IS some skepticism associated with their performance and cost. Engineers have been working to address these concerns. A unique limitation of energy conversion systems such as wind and solar is their inability to track peak power production efficiently at varying wind speeds and solar insolation respectively. This has led to control algorithms referred to as MPPT algorithms. These aid wind and solar energy conversion systems in extracting the maximum available power for a given wind and solar resource.

This thesis analyzes conventional methods of MPPT in wind conversion systems, including the popular Hill Climb Search (HCS) method. After demonstrating the limitations associated with this legacy method, a new adaptive control algorithm for MPPT is proposed. A novel algorithm is proposed which has the benefits of HCS, while eliminating the limitations of the HCS method. Some of the assumptions made as the algorithm is proposed are as follows. Continuous operation of the turbine is assumed, which means that the boost converter is in continuous operation mode. Also the mechanical characteristics of the turbine-generator set, e.g. inertia, have been discarded. The proposed algorithm maintains a similar approach to HCS method.

This is to ensure that the simplicity associated with the HCS method is preserved. Another characteristic of the proposed algorithm is an adaptive duty cycle, in contrast to the HCS method where the duty cycle is constant throughout the search. The step size is constant as in HCS method until the search is within close vicinity of the peak power. Once the search has approached the peak, the step cycle is adaptively adjusted. If the last operating point is on the positive slope side of the power curve, the increment in duty cycle is reduced to 25% of its present value. While if it had already crossed the peak but still in close vicinity of the peak power, then the direction of perturbation is changed and again the same process is repeated.

## II. SYSTEM MODELING

In the process of developing a laboratory-scaled dc microgrid platform, WECS related system configuration is shown in Fig. 1. In small scale variable speed WECS, direct driven permanent magnet synchronous generator (PMSG) with diode rectifier is the most preferred configuration due to PMSG's high air-gap flux density, and high torque-to-inertia ratio. Its decoupling control performance is much less sensitive to the parameter variations of the generator.

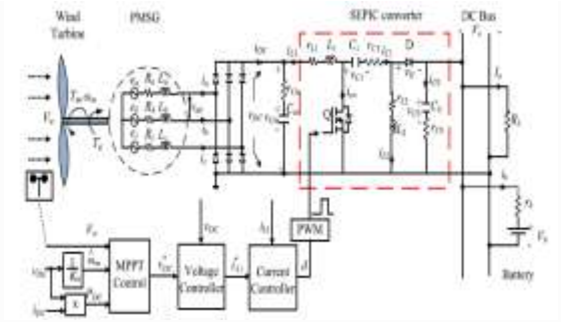

Fig:1. WECS configuration.

Among the conventional dc–dc converters, boost converter is one of the frequently used dc–dc converters in distributed generation systems, because of its higher efficiency in energy transfer. However, it can able to transfer energy only when its output stage voltage is higher than the input stage voltage.

This situation still becomes worse during sudden wind gusts. To extract wind energy from total range of wind velocity profile, a buck–boost featured dc–dc converter is preferable than boost converter as a universal converter. Among the various buck–boost converters, SEPIC dc–dc converter is better choice for WECSs, because it possesses the merits of non inverting polarity, easy-to drive switch, and low input-current pulsations, which mitigate the generator's torque pulsations.

Normal wind energy conversion is relatively straightforward process, but in order to capture the maximum power from the wind, the process is much more involved. It can be observed that the maximum of the power curve, for a particular wind speed, occurs at a particular rotor speed. Due to the aerodynamic characteristics of a wind turbine, a small variation from the optimum rotor speed will cause a significant decrease in the power extracted from the wind. Turbines do not naturally operate at the optimum wind speed for any given wind velocity because its rotor speed is dependent on the generator loading as well as the wind speed fluctuations.

Because of this, non-optimized conversion strategies lead to a large percentage of wasted wind power. The more energy extracted from the wind, the more cost effective the wind energy becomes. Because the TSR is a ratio of the wind speed and the turbine angular rotational speed, the optimum speed for maximum power extraction is different for each wind speed, but the optimum TSR value remains the same. As an example, figure 2 and 3 are the power and torque characteristics of the wind turbine used in this study.

The power and torque characteristics illustrated by Figure 2 and Figure 3 are similar to the characteristics of typical fixed pitch wind turbines. Fixed-speed wind turbine systems will only operate at its optimum point for one wind speed. So to maximize the amount of power captured by the turbine, variable-speed wind turbine systems are used because they allow turbine speed variation. Power extraction strategies assesses the wind conditions and then forces the system to adjust the turbine's rotational speed through power electronic control and/or mechanical devices so that it will operate at the turbine's highest aerodynamic efficiency.

The primary challenge of wind energy systems is to be able to capture as much energy as possible from the wind in the shortest time. From the electronics point of view, this goal can be achieved through different converter topologies and maximum power point tracking (MPPT) algorithms.

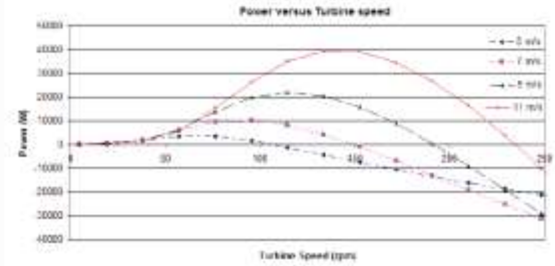

Fig:2. The power characteristic of the wind turbine used in this study.

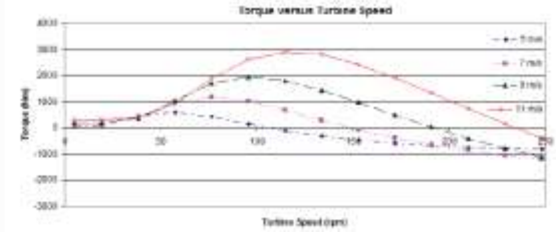

Fig:3. The torque characteristic of the wind turbine used in this study.

### III. SIMULATION RESULTS

A simulation diagram of adaptive maximum power point tracking control algorithm for wind energy conversion systems has been developed for the performance evaluation of the proposed MPPT control algorithm in extracting maximum power by a given WECS.

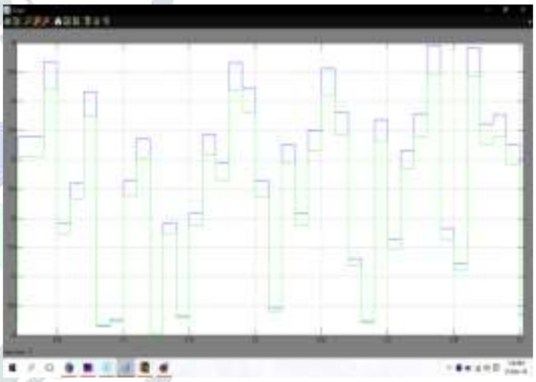
Fig.4. SEPIC's reference signal tracking response.

SEPIC dc–dc converter's response in reference signal tracking with double loop current mode controller has been verified and is shown in Fig. 4. The observed performance ensures that the tracking behavior of the converter is satisfactory even at wide variations in reference signal.

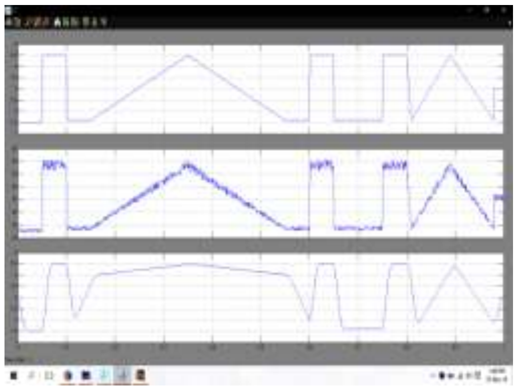
Fig.5 Dynamic response under varying wind conditions.

Fig.5 shows performance of the WECS with proposed MPPT algorithm under sudden and gradual varying wind conditions. In Fig. 5, at time *t*1, when system experiences a sudden variation in wind velocity from 4.5 to 6.5 m/s, algorithm executes turbulent wind condition related computations and searches the lookup table for $v$DCopt at the index wind velocity of 6.5 m/s. Since the data at $v$DCopt is 86.81, algorithm implements PSF feature and provides reference signal immediately to the controller without any random search process. During next sampling time, ($t$1 + 25 ms), since the wind velocity remains at 6.5 m/s, algorithm implements HCS feature and updates the programmable memory's $P$DCmax and $v$DCopt if it observes that ($t$1 + 25 ms)>$P$DC($t$1 ). At $t$2, when wind velocity reduces to 5 m/s, algorithm retrieves optimal characteristics from the lookup table and generates reference signal $v$DCopt as 82.11 V by implementing PSF feature of the algorithm under turbulent wind condition related computations. From $t$2 to $t$3, performance of the WECS is observed during gradual variations in wind velocity from 4.75 to 7 m/s and then from 7 to 4.75 m/s. Variations in power coefficient between $t$1 and $t$3 are nearly 4.7 and this ensures the optimal performance of the system throughout the duration under turbulent and gradual wind varying conditions.

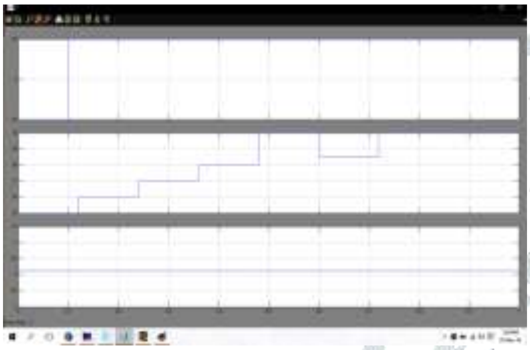

Fig.6 Performance with HCS algorithm

In Fig. 6, at instant $t$1, when wind velocity changes suddenly from 5 to 6.5 m/s, HCS algorithm needs four adjustment cycles before reaching to the optimal operating point. Time lapse between $tn$ and $tn$+1 is 1.5 s and is given to allow the wind turbine emulator to respond for the changes in wind velocity and load. According to proposed algorithm extracts 2.0625 Wh, whereas HCS algorithm extracts 1.3875 Wh against similar wind profile from $t$1 to $t$7. System response with HCS algorithm against gradual variations in wind velocity. During continuous variations in wind velocity from instant $t$1, system tries to track the MPP. However, fluctuations in wind velocity cause the searching process to start from an arbitrary point every time and this makes the tracking performance inefficient. This is indicated by the deviations in $Cp$ from its optimal point.

Fig.7 Performance with proposed algorithm

Whereas, proposed algorithm provides reference signal $v$DCopt ($k$ + 1) = 86.81 V by using lookup table data and it places the system promptly at MPP without any arbitrary variations as shown in Fig. 7. Whereas proposed algorithm makes the system to track MPP immediately without any intermediate random search operations as shown in Fig. 7. By observing the variations in $Cp$, it can be concluded that WECS with proposed algorithm harvests more energy than with HCS algorithm.

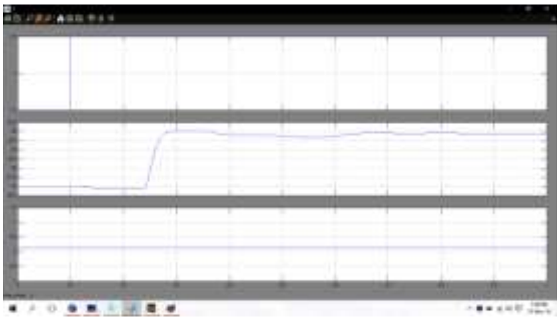

Fig.8 Performance with HCS algorithm

In the future extension, the Performance with HCS algorithm by the PR controller method. It will reduces oscillations in voltage and power and smoothen the load variation. Whereas proposed algorithm makes the system to track MPP immediately without any intermediate random search operations as shown in Fig. 8. By observing the variations in $Cp$, it can be concluded that WECS with proposed algorithm harvests more energy than with HCS algorithm.

## IV. CONCLUSION

In this paper, an adaptive MPPT control algorithm has been proposed for the fast tracking of MPP under turbulent wind conditions for small-scale WECSs. System behavior with proposed algorithm under fast changing wind conditions has been observed and it is evident that the proposed control algorithm can put the system at optimal operating point promptly against random variations in the wind velocity. System performance with proposed algorithm is compared with the HCS algorithm and experimental results proved that WECS with proposed algorithm harvests more energy than with HCS algorithm. The proposed algorithm provides the following advantages: 1) improved dynamic response of the system; 2) prerequisite of system's optimal characteristics data is not required and hence the algorithm is adaptive; and 3) algorithm's continuous modifications on programmable memory towards optimal characteristics of the system, eliminate the possibility of system's performance degradation due to parameters variations. To extract maximum power from the wide range of wind conditions, SEPIC converter is used for the implementation of proposed MPPT algorithm. Since small-scale WECSs are main resources for DERs in microgrid systems, the proposed algorithm is very much applicable for microgrid systems.

## V. REFERENCES

[1] D. S. Zinger and E. Muljadi, "Annualized wind energy improvement using variable speeds," *IEEE Trans. Ind. Appl.*, vol. 33, no. 6, pp. 1444–1447, Nov./Dec. 1997.

[2] A. Miller, E. Muljadi, and D. Zinger, "A variable speed wind turbine power control," *IEEE Trans. Energy Convers.*, vol. 12, no. 2, pp. 181–186, Jun. 1997.

[3] R. Chedid, F. Mrad, and M. Basma, "Intelligent control of a class of wind energy conversion systems," *IEEE Trans. Energy Convers.*, vol. 14, no. 4, pp. 1597–1604, Dec. 1999.

[4] H. Li, K. Shi, and P. McLaren, "Neural-network-based sensorless maximum wind energy capture with compensated power coefficient," *IEEE Trans. Ind. Appl.*, vol. 41, no. 6, pp. 1548–1556, Nov./Dec. 2005.

[5] A. S. Satpathy, N. Kishore, D. Kastha, and N. Sahoo, "Control scheme for a stand-alone wind energy conversion system," *IEEE Trans. Energy Convers.*, vol. 29, no. 2, pp. 418–425, Jun. 2014.

[6] S.Morimoto, H. Nakayama,M. Sanada, andY. Takeda, "Sensorless output maximization control for variable-speed wind

generation system using ipmsg," in *Proc. IEEE 38th Ind. Appl. Annu. Meeting Conf. Rec.*, 2003, vol. 3, pp. 1464–1471.

[7] R. M. Hilloowala and A. M. Sharaf, "A rule-based fuzzy logic controller for a pwm inverter in a stand alone wind energy conversion scheme," in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting Conf. Rec.*, 1993, pp. 2066– 2073.

[8] V. Galdi, A. Piccolo, and P. Siano, "Designing an adaptive fuzzy controller for maximum wind energy extraction," *IEEE Trans. Energy Convers.*, vol. 23, no. 2, pp. 559–569, Jun. 2008.

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