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Adaptive Maximum Power Point Tracking Control Algorithm for Wind Energy Conversion Systems


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Abstract:
This paper presents an adaptive maximum power point tracking (MPPT) algorithm for small-scale wind energy conversion systems (WECSs) to harvest more energy from turbulent wind. The proposed algorithm combines the computational behavior of hill climb search, tip speed ratio, and power signal feedback control algorithms for its adaptability over wide range of WECSs and fast tracking of maximum power point. In this paper, the proposed MPPT algorithm is implemented by using buck–boost featured single-ended primary inductor converter to extract maximum power from full range of wind velocity profile. MATLAB/SIMULINK results show that tracking capability of the proposed algorithm under sudden and gradual fluctuating wind conditions is efficient and effective.

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:
Wind energy conversion systems 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.

Wind energy, even though abundant, varies continually as wind speed changes throughout the day. The amount of power output from a wind energy conversion system (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. This study provides a review of past and present MPPT controllers used for extracting maximum power from the WECS using permanent magnet synchronous generators (PMSG), squirrel cage induction generators (SCIG) and doubly fed induction generator (DFIG). These controllers can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control.

The chapter starts with a brief background of wind energy conversion systems. Then, main MPPT control methods are presented, after which, MPPT controllers used for extracting maximum possible power in WECS are presented. Microgrid is essentially a collection of distributed energy resources (DERs), potential energy storage devices, and loads connected together to form a relatively small-size distribution network. Small-scale WECSs are main resources for DERs in microgrid systems and are usually installed at congested places with turbulent wind conditions where wind speed and direction vary frequently.

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Extraction of maximum power with fast tracking control strategy under fluctuating wind conditions is a challenging issue. In small-scale WECSs, power conditioning converter's control is most frequently adapting strategy to extract maximum power since pitch angle control is impractical due to their mechanical structure. In this work buck–boost featured single-ended primary inductor converter (SEPIC) dc–dc converter has been used to extract maximum power from total range of wind velocity profile. This work assumes that the WECS has effective yaw mechanism to turn the turbine nacelle in the direction of the wind immediately against to the variations in wind flow direction.

In this paper, a hybrid nature of MPPT control algorithm which combines the computational behavior of HCS-TSR-PSF algorithms for system independent adaptively and fast tracking capability of MPP is presented. The proposed MPPT algorithm has been evaluated by using a laboratory scaled DC motor drive based WECS emulator. Experimental results show that the proposed algorithm enables the WECS to harvest more energy by tracking the MPP under turbulent wind conditions.

The proposed algorithm in this thesis takes an initial guess for the optimum TSR and subsequently uses it to calculate the starting reference signal. The system is then adjusted towards the optimum point by using a modified version of HCS (hill climb searching). Once an optimum point has been determined, it is stored and used when the corresponding wind speed occurs again to speed up the determination process.

The algorithm also automatically determines a more accurate tip speed ratio for the turbine each time an optimum point is found. The establishment of the determined tip speed ratio facilitates more accurate estimations of the optimum operating point for wind speeds that have not yet occurred. The algorithm requires the turbine blade radius and gear ratio, but they are easy to obtain parameters so it can be easily configured to adapt to any turbine. These features of the proposed algorithm allow it to be fast, effective, and flexible. Renewable energy resources, especially wind energy, are attracting great attention with the depletion of existing fossil fuel deposits and increasing concerns about CO2 emissions. Since the late 1990s, variable speed constant frequency (VSCF) wind energy conversion systems (WECS) have been widely adopted in order to maximize wind energy utilization. The doubly-fed induction generator (DFIG) and direct-drive permanent magnet synchronous generator (PMSG) are the most popular systems for VSCF wind energy conversion.

The direct-drive PMSG has attracted more and more attention due to its advantages of high efficiency and high reliability. The configuration of a typical direct-drive WECS with PMSG is shown in Figure 1. The PMSG converts the mechanical power from the wind turbine into ac electrical power, which is then converted to dc power through a converter with a dc link to supply the dc load. By using an additional inverter, the PMSG can supply the ac electrical power with constant voltage and frequency to the power grid.

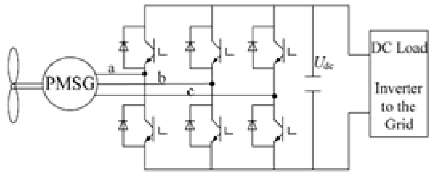

Fig:1. Configuration of a direct-drive PMSG WECS.

II. SYSTEM MODELING

In the process of developing a laboratory-scaled dc microgrid platform, WECS related system configuration is shown in Fig. 2. 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.

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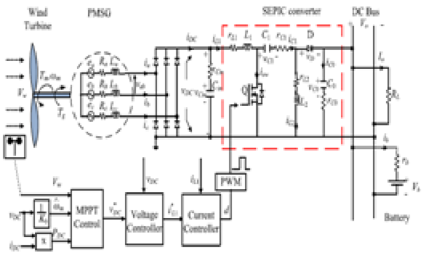

Fig:2. WECS configuration.

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 3 and 4 are the power and torque characteristics of the wind turbine used in this study. The power and torque characteristics illustrated by Figure 3 and Figure 4 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.

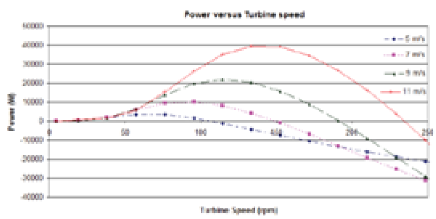

Fig:3. The power characteristic of the wind turbine used in this study.

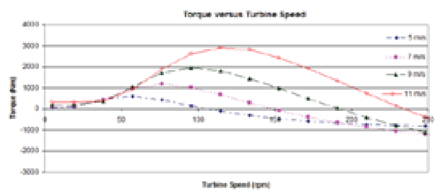

Fig:4. The torque characteristic of the wind turbine used in this study.

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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.

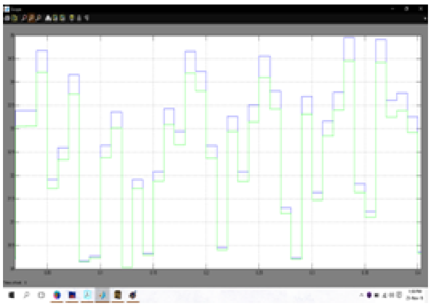

Fig.5. SEPIC's reference signal tracking response.

SEPIC dc–dc converter's response in reference signal tracking with double loop current mode controller has been verified and is shown in Fig. 5. The observed performance ensures that the tracking behavior of the converter is satisfactory even at wide variations in reference signal.

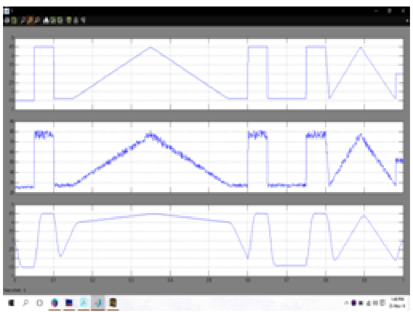

Fig.6 Dynamic response under varying wind conditions.

Fig.6 shows performance of the WECS with proposed MPPT algorithm under sudden and gradual varying wind conditions. In Fig. 6, at time t1, 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 vDCopt at the index wind velocity of 6.5 m/s. Since the data at vDCopt is 86.81, algorithm implements PSF feature and provides reference signal immediately to the controller without any random search process. During next sampling time, (t1 + 25 ms), since the wind velocity remains at 6.5 m/s, algorithm implements HCS feature and updates the programmable memory's PDCmax and vDCopt if it observes that (t1 + 25 ms)>PDC(t1). At t2, when wind velocity reduces to 5 m/s, algorithm retrieves optimal characteristics from the lookup table and generates reference signal vDCopt as 82.11 V by implementing PSF feature of the algorithm under turbulent wind condition related computations. From t2 to t3, 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 t1 and t3 are nearly 4.7 and this ensures the optimal performance of the system throughout the duration under turbulent and gradual wind varying conditions.

Fig.7 Performance with HCS algorithm

In Fig. 7, at instant t1, 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 t1 to t7. System response with HCS algorithm against gradual variations in wind velocity. During continuous variations in wind velocity from instant t1, system tries to track the MPP.

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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.8 Performance with proposed algorithm

Whereas, proposed algorithm provides reference signal vDCopt (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. 8. 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.

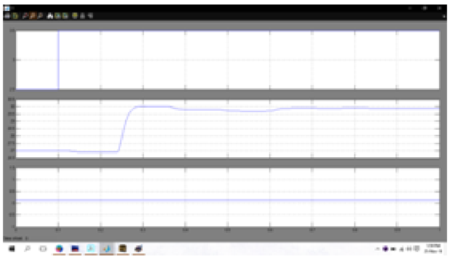

Fig.9 Performance with HCS algorithm

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. 9.

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.

[9] A. Raju, B. Fernandes, and K. Chatterjee, “A upf power conditioner with maximum power point tracker for grid connected variable speed wind energy conversion system,” in Proc. IEEE 1st Int. Conf. Power Electron. Syst. Appl., 2004, pp. 107–112.