A REVIEW ON MPPT TECHNIQUES FOR WIND ENERGY

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ABSTRACT:

The purpose of this study is to presents a new adaptive control algorithm for maximum power point tracking (MPPT) in wind energy systems. Owing to its sustainable and renewable energy sources, wind energy systems are being closely investigated. Because of its unpredictability, the principles of power management are central to the development of full power by the wind. The proposed control algorithm enables the generator to monitor the optimal wind turbine operating points under fluctuating wind conditions and speeds up the monitoring process over time. This algorithm does not need to learn the mechanical characteristics of an immaterial turbine, such as its curve of power coefficient, strength characteristics or torque. The algorithm uses its memory feature to adjust to a certain wind turbine and deduce the best rotor rate at unparalleled wind speeds. The proposed algorithm is implementing its power management framework with a updated version of Hill Climb search (HCS). The algorithm is ideally suited for wind energy systems with smaller grids or batteries.

KEYWORDS: MPPT Techniques, Wind Energy, Hill Climb search, monitoring process, wind energy systems.

1. INTRODUCTION

Wind energy conversion systems have been attracting wide attention as a renewable energy source since fossil fuel supplies are being exhausted and because environmental concerns are directly caused by fossil fuel use and nuclear power. Even if plentiful, the wind energy varies constantly with the wind speed increasing all day. The power output of a wind energy conversion system (WECS) depends on the precision with which the peak power output points are monitored by the WECS control system's maximum power points tracking (MPPT). This study analyses past and current MPPT controls used with Permanent Magnetic Synchronous Generators (PMSGs), Squirrel Cage Induction Generators (SCIG) and doubly fed induction generator (DFIGs) to produce full electricity from the WECS. This system is divided into three main controls: TSR, PSF control and hill-climb search (HCS). These controllers can also be grouped into three main control methods. The study starts with a brief overview of wind turbine systems [4]. The key MPPT control processes are subsequently introduced which are controlled by MPPT controllers used in WECS to obtain full capacity.

Wind is the most promising renewables to substitute fossil fuel in the near future as one of the most used renewable energies [5]. The maximum power point tracking (MPPT) monitoring of variable-speed operating systems, as a DFIG (Double Fed Induction Generator) and permanent magnet synchronous generation systems, attracts considerable attention in order to achieve a high efficiency within a wind power conversion system.

The studied MPPT methods in the history include three strategies, namely:

- Methods relying on wind speed;
- Methods relying on output power measurement and calculation; and
- Methods relying on characteristic power curve.

The wind energy measurements are used for most wind power control systems. These systems typically require anemometers to measure the velocity of the wind. The additional costs and complexity of these systems are impaired. Methods for estimating wind speed have been reported in order to solve this problem. The wind speed can be captured to monitor the optimum tip-speed ratio, based on complex software algorithms, for the application of MPPT [6]. Therefore, it could be introduced to track the full power directly by calculating the output power. The idea of this method is the online measurement of the output power and checking the rate of change of power with respect to speed, i.e., $\frac{dP}{dW}$ to extract maximum power from the wind turbine system. MPPT can be achieved when $\frac{dP}{dW} = 0$ through adjusting either the rotor speed or duty cycle of the converter.

The approach is based on a large amount of online computing and therefore MPPT for rapidly shifting wind speeds will be hard to achieve. While it is possible to use the varied tracking stage to increase computation speed, this downside cannot be eliminated. Recently, due to its simplicity of hardware and software, a suggested method of using the power versus the rotor speed characteristic curve was sometimes used [7]. The best reference power curve can be constructed and programmed in a microcontroller memory according to experimental tests. Either the rotor speed can be calculated or the power reference used to regulate power or the wind speed can be calculated and a rotor speed reference to control the rotor speed can be obtained. The first generates a more precise output, while the second has a more rapid control response. In order for the system to be reliable to verify the variance of wind speed and output power, an experiment is required, apart from an exact reference power curve. Few publications deal only with the stability issue of this system, but a more thorough quantitative analysis should be carried out. This paper examines the wind turbine output in the MPPT power control reference curve [8].

The study of generating speed dynamics caused by variable wind speed in particular requires small-signal study. An experimental setup is also provided to simulate the operation of the wind turbines in torque control mode. The research and conclusions presented are confirmed by both stable and dynamic responses.

2. MPPT METHODS

There are different methods used to track the maximum power point. Few of the most popular methods are:

1) Perturb and observe (hill climbing method)

2) Incremental Conductance method

3) Fractional short circuit current

4) Fractional open circuit voltage

5) Neural networks

6) Fuzzy logic

2.1. Perturb & Observe method

Perturb & Observe (P&O) is the simplest method. We use only one sensor, namely the voltage sensor, to feel the voltage of the PV array, making it less expensive to implement. The time complexity of this algorithm is much less, but it does not end at MPP and continues in both directions when it reaches very close to MPP. If this occurs we can set a correct error limit for the algorithm, or use a wait function which ultimately increases the algorithm’s time complications. However, the approach does not take account of the rapid irradiation level adjustment (which induces changes to the MPPT) and treats this as a disturbance shift in the MPP and ends up measuring the incorrect MPP. We can use incremental behavior method to avoid this problem.

2.2. Incremental Conductance method

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array.

At MPP the slope of the PV curve is 0.

$$\left(\frac{dP}{dV}\right)_{MPP} = d(VI)/dV$$

$$0 = I + VdI/dV_{MPP}$$

$$\frac{dI}{dV_{MPP}} = -I/V$$

The immediate conduction of the solar panel is on the left hand side. If this instantaneous conductance corresponds to solar conductance, then MPP is achieved. Here we simultaneously feel the voltage and the current. This eliminates the mistake due to changes in irradiance. The complexity and implementation costs however are rising. The complexity and implementation costs of a highly complex system continue to expand with our list of algorithms. That's why the most commonly used algorithms are the Perturbing and Observing and Gradual Process.

2.3. Fractional open circuit voltage method

The near linear relationship between V_{MPP} and V_{OC} of the PV array, under varying irradiance and temperature levels, has given rise to the fractional V_{OC} method.

$$V_{MPP} = k_1 V_{oc}$$

Where k_1 is proportionality constant. Since k_1 depends on the features of the pv array to be used, empirical determination of VMPP and VOC for the same pv array can typically be determined in advance at various irradiance and temperature rates. Factor k_1 between 0.71 and 0.78 was registered. If k_1 has been learned, VMPP can be determined periodically by shutting off the power converter with VOC measured for an instant. But there are other inconveniences, including temporary power loss.

2.4. Fractional short circuit current method

Fractional ISC results from the fact that, under varying atmospheric conditions, IMPP is approximately linearly related to the I_{SC} of the PV array.

$$I_{MPP} = k_2 I_{sc}$$

Where k_2 is a proportionality constant. Like the fractional VOC method, the PV array in use should be used for k_2. In general, the constant k_2 ranging from 0.78 to 0.92. During operation, ISC measurement is a problem. The power converter normally needs additional switches to shorten the PV array regularly so the ISC can be measured by means of a current sensor.

2.5. Fuzzy Logic Control method

Microcontrollers popularized MPPT for the last decade with the use of fuzzy logic control. The advantages of working with inaccurate inputs are fluid logic controllers that don't need a correct mathematical model and manage nonlinearity.

2.6. Neural Networks method

Neural networks are another MPPT design technique that is well-adapted for microcontrollers. There are usually three layers for neural networks: input, secret, and output. Growing layer of nodes differs according to the user. The input variables may include the parameters of the PV array such as VOC and ISC, or of atmospheric data such as radiance and temperature. Output is typically one or more benchmarks such as a duty cycle signal to operate at or near the MPP converter.

Table 1: Characteristics of different MPPT Methods

MPPT Methods	**Convergence Speed**	**Implementation Complexity**	**Periodic tuning**	**Sensed Parameters**
Peturb & Observe	Varies	Low	No	Voltage
Incremental Conductance	Varies	Medium	No	Voltage Current
Fractional	Medium	Low	Yes	Voltage
Fractional	Medium	Medium	Yes	Current
Fuzzy logic Control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

3. CHARACTERISTIC EQUATIONS OF VARIABLE WIND TURBINE

The following equations describe the wind turbine characteristics.

$$P_m = \frac{1}{2}\rho A v^3 C_p(\lambda, \beta) \qquad (1)$$

$$\lambda = \frac{R\omega}{v} \qquad (2)$$

$$C_p(\lambda, \beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\frac{-21}{\lambda_i}} + 0.068\lambda \qquad (3)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \qquad (4)$$

Wind turbine Torque equation is

$$T_m - T_e - F.\omega = J\frac{d\omega}{dt} \qquad (5)$$

Where Pm - mechanical output power of wind turbine(W) , ρ- density of air (kg/m3), A-turbine swept area(m2), v - wind speed(m/sec) , R - turbine radius (m) , $CP(\lambda, \beta)$ power coefficient of wind turbine , ω - turbine angular velocity(rad/sec) , β- blade pitch angle(deg), λ-tip speed ratio the rotor blade tip speed to wind speed , Tm -shaft mechanical torque , Te -electromagnetic torque ,F – combined viscous friction of rotor and load and J is combined inertia of rotor and load. The maximum value of CP is achieved at 0.48 for β=0 degree and for λ =8.1 is shown in Fig.1 .The particular value of λ is called the nominal value.

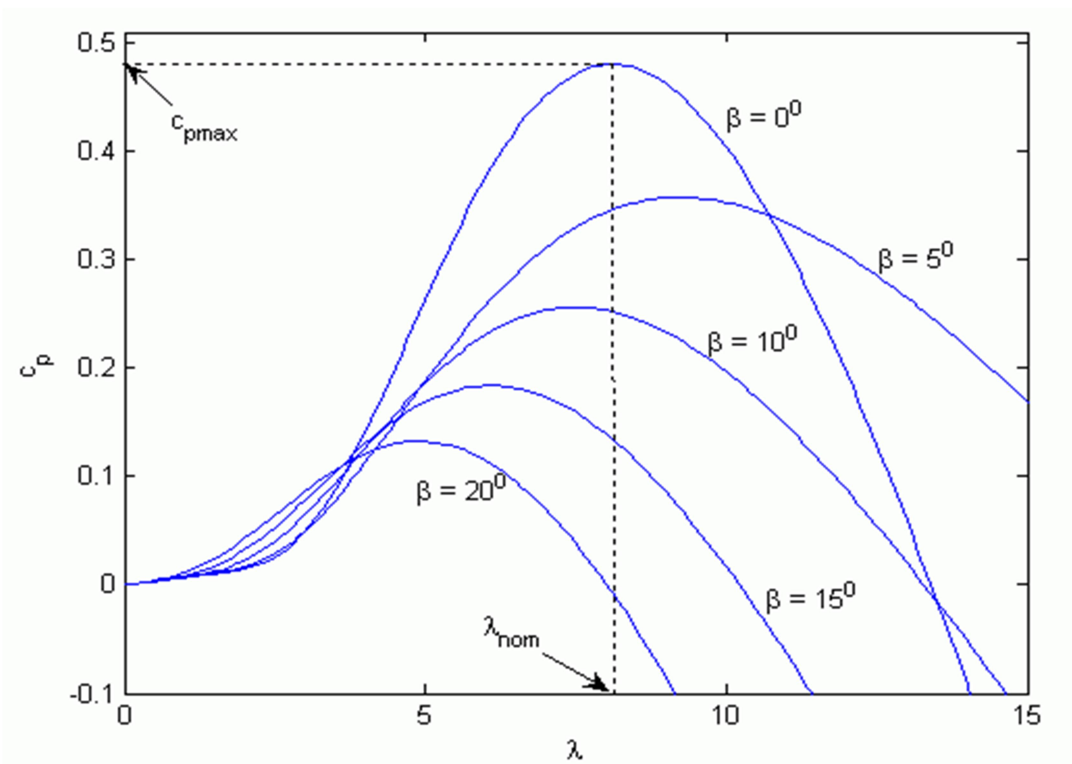

Fig.1. Coefficient of power CP versus tip speed ratio, λ (TSR)

4. PRINCIPLE OF OPERATION

The simulation of the WECS result in MATLAB software by a 2MW D-PMSM with a 2 MW wind turbine. In Fig.2, it is obvious that there is a rotating velocity equal to the average power lines for each specific wind speed. The spinning speed is regulated to break the maximum power lines while the wind is shifting. The value of the optimum speed without calculating wind velocity is determined in the proposed algorithm. The proposed MPPT controller demonstrates how the maximum power point is controlled in the flow chart Fig.3[1].

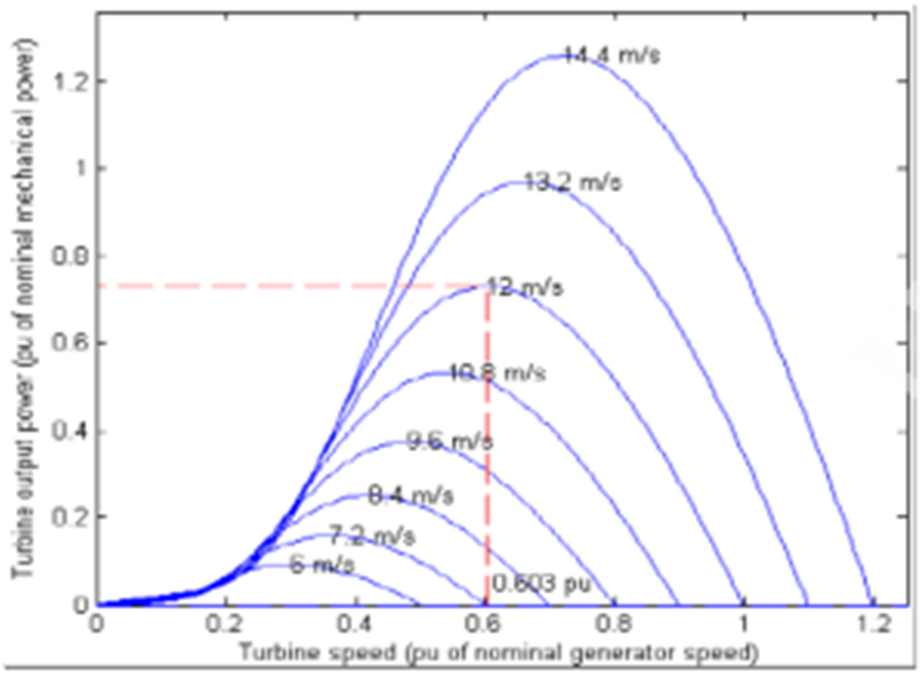

Fig.2. Wind turbine power characteristics

The values of K are calculated by the use of different simulations and selection of those that produce the best results. If the power is increased in the current sampling moment, i.e. $\Delta Pm\ (n) > 0$, the command speed ωr is increased. If the power in present sampling instant is found to be decreased, i.e. $\Delta Pm\ (n) < 0$, then, the command speed is decremented.

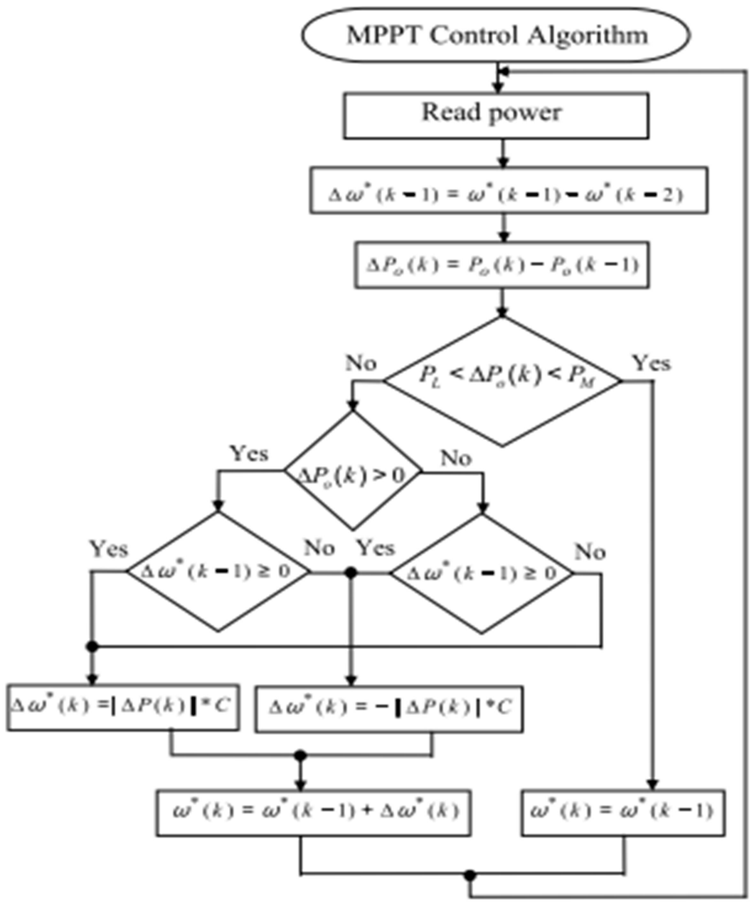

Fig.3.Flow chart diagram of MPPT controller

5. MAXIMUM POWER POINT TRACKING CONTROL

As a renewable energy source, the wind power system has been attracted by the decline of fossil fuel supplies and environmental issues as a direct result of the use of nuclear and fossil fuel [13]. Even if plentiful, the wind energy varies constantly with the wind speed increasing all day. The power supply of the WECS is determined by its exactness, regardless of the form of generator that is used, by the MPPT controller of the WECS controller [10]. Three major control techniques, namely TSR control, Power Signals Feedback Control and Hill-clicking Search (HCS) control [2], can be classified for the maximum power extraction algorithm researched so far.

The TSR control mechanism controls the generator's rotational speed to hold the TSR at an optimal value for the maximum energy extracted [11]. This method requires the calculation or estimate of both the wind speed and the turbine speed, in order to obtain maximum efficiency, as well as requiring the knowledge of the optimum Turbine TSR. fig. 4 Displayed the TSR power WECS block diagram.

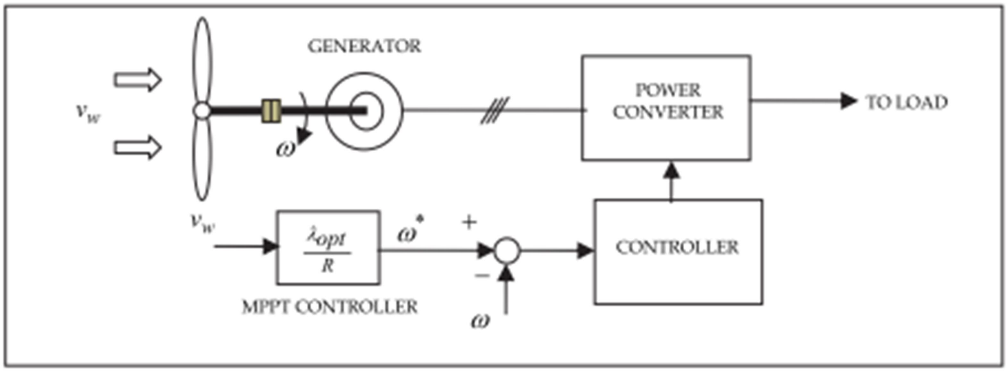

Fig. 4. Tip speed ratio control of WECS

With PSF control, it is important to know the maximum power curve of the wind turbine and monitor it through its control mechanisms. Using simulations or an off-line experiment on the individual wind turbines to achieve the full power curves [12]. This approach produces reference power either by means of a recorded maximum power curve or by means of the mechanical wind turbine power equation in which wind speed or rotor speed are used as input. fig. 5 Displays the WECS block diagram for full power recovery with a PSF controller.

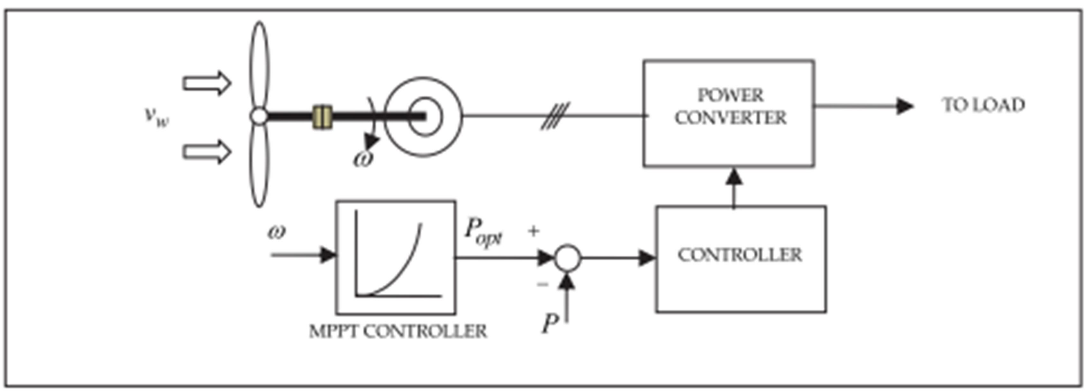

Fig. 5. Power signal feedback control

The HCS control algorithm searches continuously for the wind turbine's peak power. Some of the common issues normally linked to the other two methods can be solved [14]. The tracking algorithm determines the optimal optimum signal to move the device to full power, based on the location of the operating point and the relation between power change and speed changes. fig. 6 displays the HCS and Fig 7 principle. Show WECS for tracking maximum power points with the HCS controller [15].

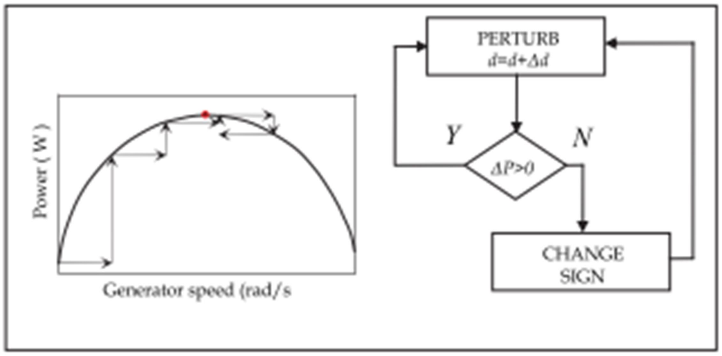

Fig. 6. HCS Control Principle

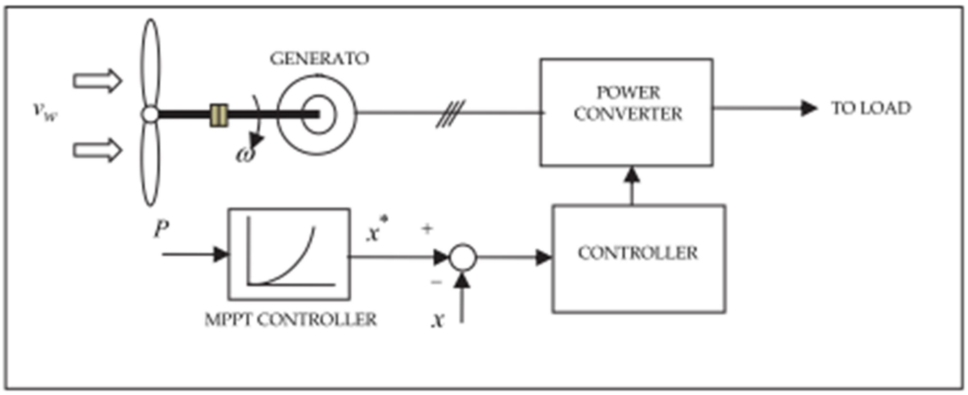

Fig. 7. WECS with hill climb search control

6. CONCLUSION

Wind energy conversion system has been receiving widest attention among the various renewable energy systems. A major area of research was to derive the full output from the available wind power, where wind speed sensors with less MPPT control are highly involved in research. A descriptive overview of MPT control methods was presented in this Study in different literatures for WECS control with different generators. Convert and control systems in hopes of providing a viable economic solution to rising environmental problems is increasingly being made more efficient and cost effective. In the last decade, wind power generation has increased at an unprecedented pace and continues to develop as the electronic power technology progresses.

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