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A Review on Modeling and MPPT algorithm for Wind Energy ConversionSystem

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Abstract:
Wind energy is one of the most widely used renewable energy source around the globe. The wind energy technology is advancing with a rapid pace and there are several existing Maximum PowerPoint tracking algorithms developed by researchers. In This paper mathematical modeling of wind energy system has been analyzed and some commonly used power electronics converter topologies are discussed. Also, an attempt has been made to analyze and compare different existing modern MPPT techniques.

Keywords:*Wind Energy Conversion, MPPT techniques, PMSG, TSR.*

I. INTRODUCTION

It is a commonly known fact that the fossil fuels that are generally used today to generate electricity like coal, diesel, petrol, etc. are getting exhausted with an exponential rate [1]. As the consumption of electricity is also increasing due to an excessive increase in population the requirement of generation is also increasing. Hence in this knotty situation every country is shifting towards the Renewable resources of energy generation such as wind, solar, tidal, geothermal etc [2].Renewable resources of energy generation are clean form of energy generator as there is no harmful emission is done by them. The agenda of sustainable development of 2030, which is received by all UN members' states in the year of 2015, also contains affordable and clean energy at 7th point [3]. Hence to maintain a sustainable development we need to have an energy which is coming from a clean source [4]. As older ways of energy generation requires the fossil fuels (which are getting deficit), the rate of electricity is also increasing which makes the electricity non affordable for most of the people [5]. This is also violating the sustainable development policy. Hence only way remain to overcome this problem is by using Renewable resources as they are clean and also do not pollute the environment [6]. In all the forms of Renewable energy, wind energy is one of the most efficient. As day by day it is getting clear, most countries have started research in it [7]. Hence Wind Energy is getting an observable increment among other forms of Renewable energy [8]. Fig 1 depicts the installed capacity of wind from 2000 till 2020. As we can see in year 2000, only 17.4 GW (approx.) of wind energy was installed but due to rapid growth of wind energy by the year 2020 it is expected to become an astonishing 590 GW (approx.) [9]. This paper intend to give an overview of how wind energy is converted to electrical energy and also how MPPT techniques help to get the best efficient energy with least effort [10].

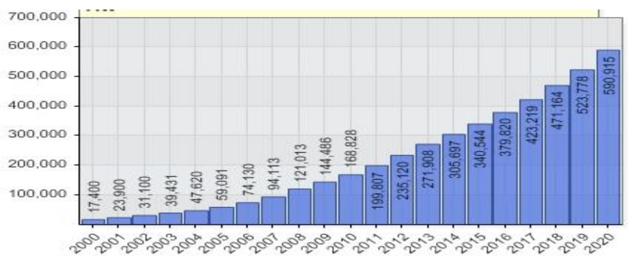

Fig.1. Cumulative installed wind capacity

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II. WIND ENERGY CONVERSION SYSTEM

Since 2000 years Wind Mill have been a helping hand for conversion of wind energy into some useful form of energy. Wind energy is used to harness electrical energy from mechanical energy [11]. To transform mechanical energy into electrical energy various subsystems or components are required [12]. The most essential part in this system is the Wind Turbine. Wind turbine of current technology are able to transform large amount of energy of the wind into electricity [13]. This is made possible by the blades developed from the aerodynamics design and different performance enhancement equipments [14].The various categories of wind turbine are HAWT (HORIZONTAL-AXIS TYPE MODEL) and the VAWT (VERTICAL-AXIS TYPE MODEL) [15].Now moving on to the basic functioning of the turbine, the power of the blowing wind will rotate the blades and electricity is generated with the help of generator present in the nacelle [16]. The generator is not directly connected to the blades because blades rotate at a very slow rate and other issues like noise. Due to this low rotation speed of blades any significant electricity cannot be generated through the generator. The speed is brought to the required level by usage of a gearbox. The Gearbox consist of various planetary gear arranged in a manner to obtain high speed from low speed. A break is also installed in the nacelle to damper high speed blade rotation in extreme weather condition. Finally the generated electricity is transferred via the cable towards the bottom where step up transformer is located. In order to obtain the Maximum power from the wind, a velocity sensing equipment is attached at the top to detect speed of the wind and it's direction. The change in the direction of wind is relayed to an electronic controller which gives back a signal to the yawing mechanism to change the direction of blades. Thus wind turbine will be in the direction of the blowing wind [17].

CLASSIFICATION OF WECS:

- LITTLE SIZE (up to 2KW):- This type of wind turbines have less power capacity, and can be used for various remote applications.
- MEDIUM SIZE (2 to 100 KW):- This type of wind turbines have a rated capacity of one hundred kilowatt
- GIANT SIZE (>100 KW):- These wind turbine are used for distribution functions and power is provided to a central grid.[23]

III. Modeling of Wind turbine:

To know about the energy available from the wind turbine we should know about the kinetic energy because wind consist of small air particles containing kinetic energy. Kinetic energy of wind is different than other objects, it have lots of small particles like nitrogen, oxygen, carbon dioxide and other things all of them moving so we can't really calculate each individual molecule so we use the mass flow of the particles.

$$\frac{dm}{dt} = \rho AV \qquad (1)$$

Where:

ρ = density of the air

A= swept are of the area calculating

V= volume of the air

The kinetic energy equation given as $P = \frac{1}{2} mV^2$ (2)

$$P = \frac{1}{2}\frac{dm}{dt}V^2 \qquad (3)$$

$$P = \frac{1}{2}\rho AV^3 \qquad (4)$$

$$C_p = \frac{P_{Wind\ turbine}}{P} \qquad (5)$$

$$P_{Wind\ turbine} = C_p P \qquad (6)$$

$$P_{Wind\ turbine} = C_p \times \frac{1}{2}\rho AV^3 \qquad (7)$$

Every Generation System is less than 100% efficient we cannot convert one form of energy into another form without losses. So if we assume that wind is blowing with 100% of its power, if we put that through turbine the maximum efficiency we can get is 59.3 %. It is known as Betz limit [18].

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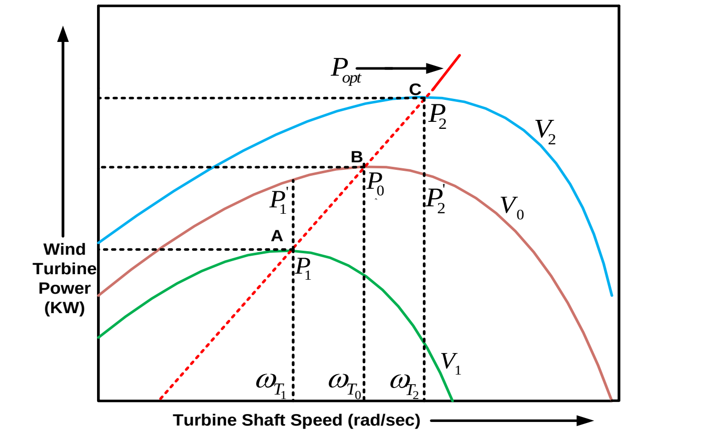
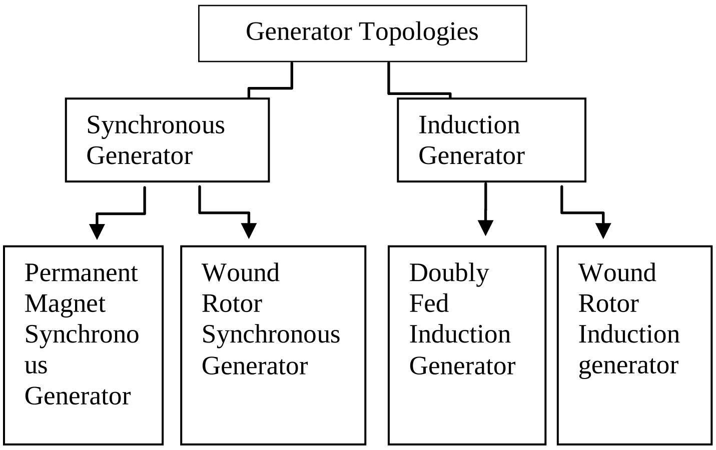


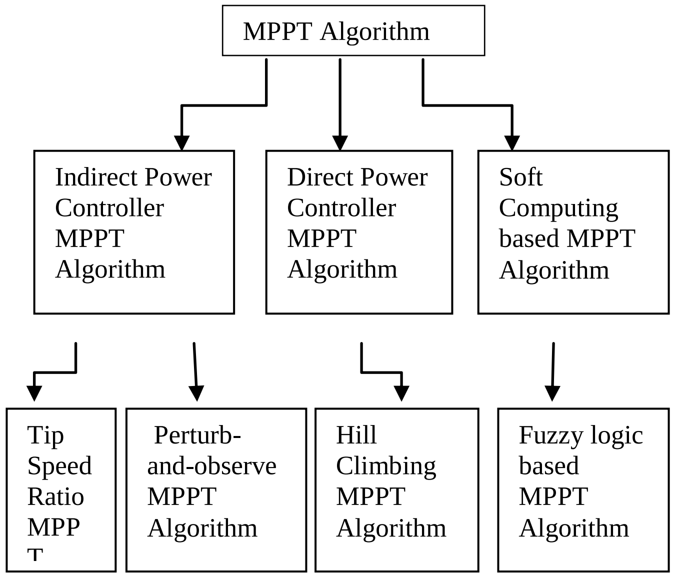
Fig.3 Graph between Wind turbine power and Turbine shaft speed

IV. Electrical Aspects of WECS:



Synchronous Generator is a self excited machine and pole pitch of machine is also smaller than that of induction generator.Hence they can be used for large power applications. Two types of Synchronous Generator are explained. Permanent Magnet Synchronous generators are usually preferred for small scale turbines as it allows high efficiency for smaller wind turbines blades . In Wound Rotor Induction Generator controlling of generator can be done by regulating the rotor circuit. The advantage of using doubly fed induction generator is that we can get output more than rated power without even getting heated in excess amount [19].In PMSG thyristor-based-grid-side inverter allow regular control of DC to AC converter firing angle and regulate turbine velocity through a DC link voltage. Thus results in optimal energy capture. While hard-switching grid-side inverter uses derived control on stator frequency and also change the DC link voltage. Back to Back PWM converter controls DC Link voltage by PI controller.

V. MPPT TECHNIQUES



In any method of energy conversion there is single point at any given time where max power can be drawn. Hence we track that point so that the operating point of conversion system is near that point. [20-24]Following are the MPPT techniques that are going to be discussed in this paper:i. P&O (Perturb-and-observe) This technique is one of the simplest and one of the most used technique to track maximum power point. In this method we track the value of slope from Power-voltage curve until it becomes zero i.e.

$$\left(\frac{dP}{dV} = 0\right)$$

(8)

Following is the flow chart of P&O technique:

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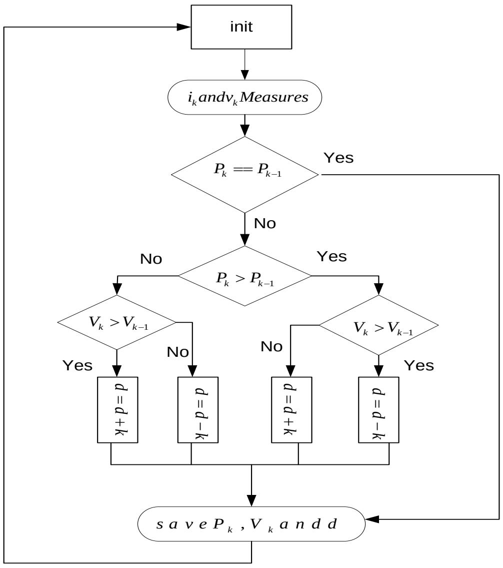

Fig.4 Flow diagram of P&O technique

Now when $\frac{dP}{dV} > 0$ then operating point is on left and hence it is moved to right and if $\frac{dP}{dV} < 0$ then operating point is at right then it is moved to left until $\frac{dP}{dV} = 0$ is reached [25]. This can also be understood by following graph.

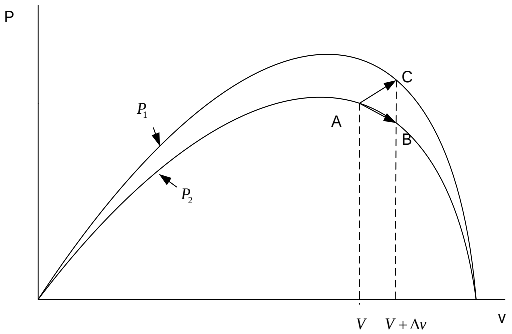

Fig.5 Graph of P&O technique

ii. Fuzzy Logic Control Method

It is one of the fastest methods of MPPT. Fuzzy logic Method use two type of algorithm for its implementation .

a. Direct MPPT (Fuzzy logic controller output is compared with other control block).

b. Indirect MPPT (Output of Fuzzy Logic controller is duty cycle of PWM index modulation) [26].

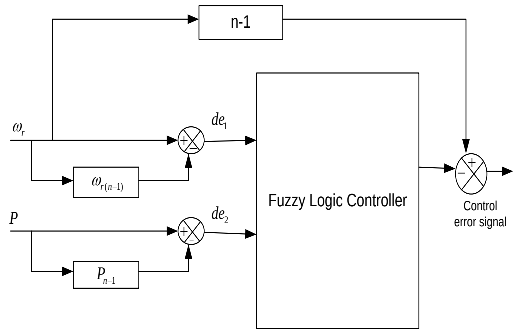

Fig.6 Block presentation of FLC

Fuzzy logic Control basically contains 3 steps Fuzzification, Rule base lookup table and Defuzzification [27].

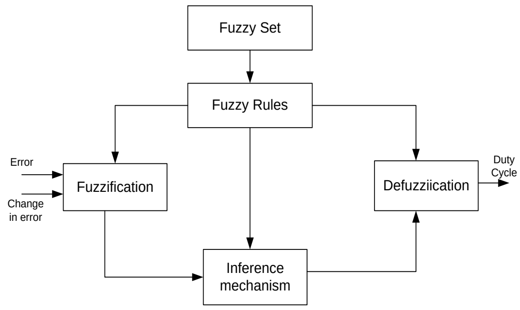

Fig.7 Basic structure of FLC

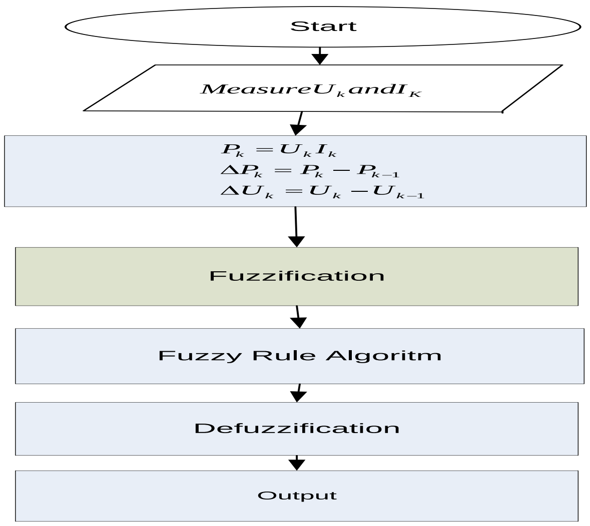

Fig.8. Flow Chart of Fuzzy Logic

iii. Hill Climbing Method

Due to shape of graph is like hill its name is hill climbing method.

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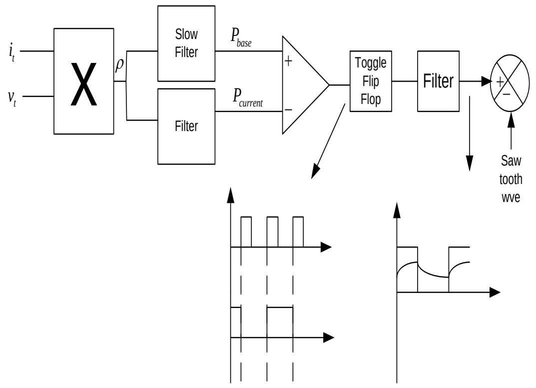

Fig.9 MPPT control Block of Hill Climbing Method

Let P_{base} line (slow moving) and $P_{current}$ (fast moving). Now, if output of block is increased the operating point will move to left the moment it encounters the P_{base} a toggle will happen and it will start to move to right and again it encounters P_{base} it will start to move towards left [28]. Now if P_{base} is also moving than the zone will become narrow and hence it can achieve MPP.

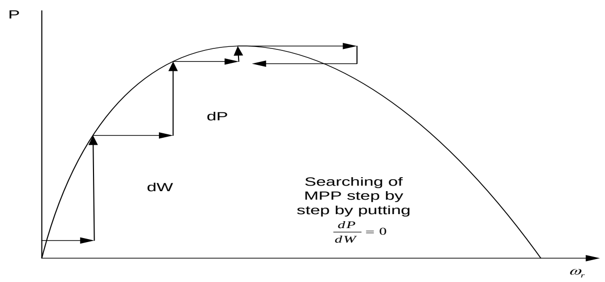

Fig.10 Graph of Hill Climbing Method

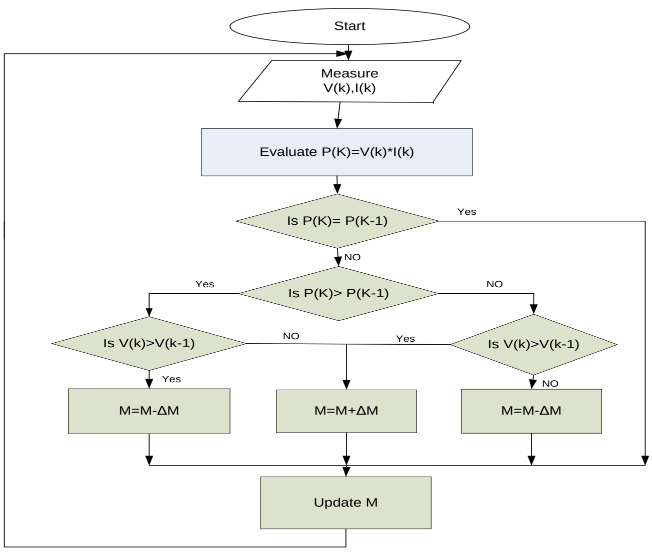

Fig 11.Flow Chart of Hill Climbing

iv. Tip Speed Ratio Technique

TSR is defined by dividing the speed of the tips of the turbine blades by the speed of the wind. In this MPPT method the rotational speed of generator is regulated in such a way that value of tip speed ratio is at max power point . In this method knowledge of optimum tip speed ratio is required as well magnitude of turbine and wind speed is required In this method when speed of wind is constant the maximum power point is measured by hill climbing method. This measured value is compared to the previously stored value, if value that is new is different from old saved value new speed is stored. Storage of value of tip speed ratio helps in finding of maximum power point at the time of variable speed of wind. Tip speed ratio technique is basically used for rapid tracking by the data that is stored from anemometer about wind speed.

The following block diagram shows about the TSR method working [30].

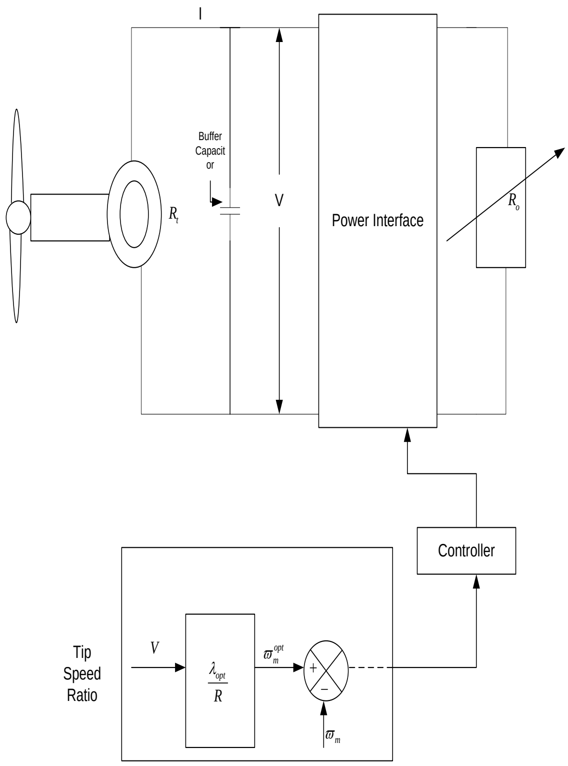

Fig.12 TSR MPPT block diagram

Table 1 Comparison of mentioned MPPT Algorithm

Algorithm	P&O	Hill Climbi	Fuzzy logic	Tip speed

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		ng		ratio
Complexity	Medium	High	High	Simple
Conversions	Medium	Fast	Medium	Fast
Memory Requirement	Yes	No	Yes	No
Wind Speed Measurement	Yes	No	Depends	Yes
Performance	Medium	Very good	Very good	Medium
Prior training/ knowledge	Essential	Not Essential	Essential	Not Essential

CONCLUSION

As there has been an increased advancement in wind power generation system there is a need for suitable MPPT technique in order to draw maximum power from source. In this paper is we have discussed about WECS and various MPPT techniques used in it. The MPPT techniques discussed in this paper are TSC, HCS, FLC and P&O because they are fast, reliable and also cost of implementation is low. Various Generator and Convertor topologies are discussed in summarized manner in paper. Also in this paper basic functioning of wind turbine and its components are explained in a brief manner with glimpse of today's scenario about efficient power generation shortage.

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