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Maximum Power Point Tracking Control for Wind Energy Conversion System Using PID Controller and Fuzzy Logic

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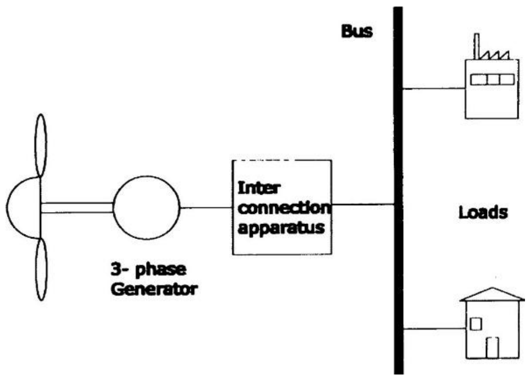
Abstract: The use of wind energy has become an important part of world sustainable energy development. Wind energy systems are being studied much because of its great benefits as it's an environment friendly and a sustainable source of energy. Due to it's this erratic nature, power maximization concepts are necessary for extraction as much power as possible from the wind energy systems. In this paper some algorithms have been discussed to preserve the system at its highest possible plenty at all times and PID controller and Fuzzy Logic is applied. The algorithms have been used to obtain the operating points for transfer of maximum power. As such, so many maximum power point tracking techniques have been implemented and developed. These algorithms are studied and analysed, a comparative analysis and improvement is performed between PID MPPT and Fuzzy based MPPT.

Keywords: MPPT, Wind Energy, PID, Fuzzy Logic, MATLAB

1. INTRODUCTION

The major components of a typical wind energy conversion system include a wind turbine, generator, interconnection apparatus and control systems, as shown in Fig 1.
Wind turbines can be classified into the vertical axis type and the horizontal axis type. Most modem wind turbines use a horizontal axis configuration with two or three blades, operating either down-wind or up-wind [2].direction the preceding point is referred by lichen Chang.



Turbine

Figure 1 Structures of Wind Energy Conversion Systems

A wind turbine can be designed for a constant speed or variable speed operation. Variable wind speed turbines can produce from 8% to 15% more energy output as compared to their constant speed counterparts, however, they necessitate power electronic converters to provide a fixed frequency and fixed voltage power to their loads. Most turbine manufacturers have opted for reduction gears between the low speed turbine rotor and the high speed three-phase generators.

There are a number of wind turbine technologies, and they have different capabilities and effects with respect to these power systems issues. In the light of such issues, wind turbine configurations and farm models are being more carefully examined to determine their potential and limitations [3]. The first wind turbines were typically constant speed turbines with induction machines and gearboxes connected directly to the grid. This configuration is still common in Denmark; it is the least flexible configuration, and has the greatest negative impact, sometimes necessitating the installation of compensating devices.

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The majority of large turbines being installed today are much more sophisticated variable-pitch, variable speed turbines with Doubly-Fed Induction Machine Generators (DFIGs). Such systems achieve variable speed operation (which is desirable to increase energy capture and reduce blade loading) at minimum cost [2]. They employ a back-to-back power electronic converter to energize the rotor windings of the doubly-fed machine through a connection to the grid. Because of this, they also offer control of reactive power at the grid interface.

The electrical power generation structure contains both electromagnetic and electrical subsystems. "The system has two wind power generations systems, the Fixed 5 speed W ECS and Variable speed wind energy control system. Fixed-speed W ECS operate at constant speed. Fixed-speed W ECS are typically equipped with SCIG, soft starter and capacitor bank and they are connected directly to the grid. Initially, the induction machine is connected in motoring regime in such a way that it generates electromagnetic torque in the same direction as the wind torque. In steady-state, the rotational speed exceeds the synchronous speed and the electromagnetic torque is negative. This corresponds to the squirrel-cage induction machine operation in generation mode [Bos01]. As it is directly connected to the grid, the SCIG works on its natural mechanical characteristic, having an accentuated slope (corresponding to a small slip) given by the rotor resistance. Therefore, the SCIG rotational speed is very close to the synchronous speed imposed by the grid frequency.
The wind velocity variations will induce only small variations in the generator speed. As the power varies proportionally with the wind speed cubed, the associated electromagnetic variations are important. SCIG are preferred because they are mechanically simple, have high efficiency and claim less maintenance cost. Furthermore, they are very robust and stable. One of the major drawbacks of the SCIG is that there is a unique relation among active power, reactive power, terminal voltage and rotor speed [5]. (i.e.,) that an increase in the active- power production is possible only with an increase in the reactive power consumption, leading to a relatively low full-load power factor. In order to limit the reactive power absorption from the grid, SCIG based WECS are equipped with capacitor banks.

SCIG-based W ECS are designed to achieve maximum power efficiency at a unique wind speed. In order to increase the power efficiency, the generator of some fixed-speed WECS has two winding sets, and thus two speeds. The first set is used at low wind speed (typically eight poles) and the other at medium and large wind speed (typically four to six poles) [8].
Fixed-speed WECS have the advantage of being simple, robust and reliable, with simple and inexpensive electric systems and well proven operation. On the other hand, due to the fixed-speed operation, the mechanical stress is important. All fluctuations in wind speed are transmitted into the mechanical torque and further, as electrical fluctuations, into the grid. Furthermore, fixed-speed W ECS have very limited controllability (in terms of rotational speed), since the rotor speed is fixed, almost constant, stuck to the grid frequency. An evolution of the fixed-speed SCIG-based W ECS are the limited variable speed WECS. They are equipped with a Wound-Rotor Induction Generator (WRIG) with variable external rotor resistance. The unique feature of this WECS is that it has a variable additional rotor resistance, controlled by power electronics. Thus, the total (internal plus external) rotor resistance is adjustable, further controlling the slip of the generator and therefore the slope of the mechanical characteristic. Obviously, the range of the dynamic speed control is determined by how big the additional resistance is. Usually the control range is up to 10% over the synchronous speed.

Variable-speed wind turbines are currently the most used WECS. The variable speed operation is possible due to the power electronic converters interface, allowing a full (or partial) decoupling from the grid. The Doubly-Fed Induction Generator (DFIG)based WECS, also known as improved variable-speed WECS, is presently used mostly by the wind turbine industry.

The DFIG is a WRIG with the stator windings connected directly to the three phases, constant-frequency grid and the rotor windings connected to a back-to-back (AC— AC) voltage source converter [3], [5]. Thus. the term "doubly-fed" comes from the fact that the stator voltage is applied from the grid and the rotor voltage is impressed by the power converter. This system allows variable-speed operation over a large, but still restricted, range, with the generator behavior being governed by the power electronics converter and its controllers.

2. WIND ENERGY CONVERSION SYSTEM

Variable Speed wind generation systems are more attractive than fixed-speed systems because of the more efficient energy production, improved power quality, and improved dynamic performance during grid disturbances. By adjusting the shaft speed optimally, the variable-speed Wind Turbine Generators (WTGs) can achieve the maximum wind power generation at various wind speeds within the operational range. To attain maximum wind power extraction, most controller designs of the variable-speed WTGs employ anemometers to measure wind speed in order to derive the desired optimal shaft speed in line with the generator speed. In most cases, a number of anemometers are placed around the wind turbine at some distance to provide adequate wind speed information [1]

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What is Pitch System?

A pitch system monitors and adjusts the angle of the wind turbine blades and thus controls the rotation of the rotor. When the speed of the wind is lower, the ideal angle accelerates the rotor rotations speed, while at higher speeds; the blade pitch control reduces the wind speed on the blades and structure of the turbine. Above a certain wind speed the pitch system starts to rotate the blades out of the wind, and thus slow down or stop the rotor speed according to the situation to avoid damage.

Pitch Angle Controller

This system changes the pitch angle of the plates to suit the varying speed of wind and so maximum power capacity is attained. When the speed is exceeding the rate speed, the pitch of the blade is out of phase with wind speed. The fall in out of line with wind speed led to reduction in the aerodynamic efficiency. But the pitch angle is controlled by edition angle of blade when blade is exposed to normal wind speed i.e., well in line with rated speed the pitch angle is reset in such a way that it provides maximum power output. to suit wind speed with rated speed and so generator power is made maximum B.

Pitch actuator Subsystem

The pitching of the blades is effected through gears, hydraulic or electro mechanical motors and governed by electronic controllers in order to attain an optimal control of the power output of the turbine. Modern pitch control system allows rotation each blade with different angles.

3. PROPOSED TECHNIQUE & RESULTS

The maximum power is computed online using a modified perturb and observe algorithm. The computed maximum power is compared with instantaneous actual WIND power, the error between reference (maximum) power and actual power activates ON/OFF controller with a hysteresis band to drive the buck chopper. Therefore, the instantaneous power extracted from the WIND is maintained between the tolerance bands.

PID BASED WIND POWER

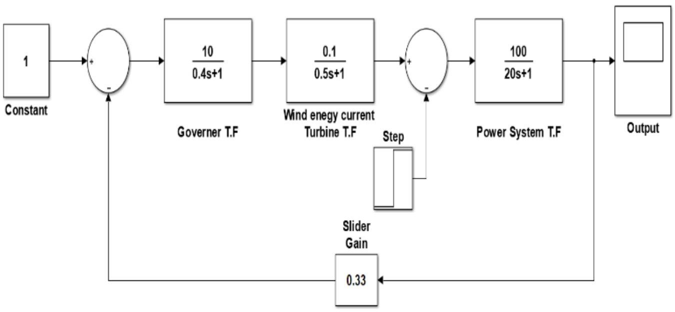

Figure 2: PID Controller Wind Energy Conversion System

Figure 2 represents PID based Wind Power System on the basis of power transfer function. The resulting waveforms are given in Figure 3.

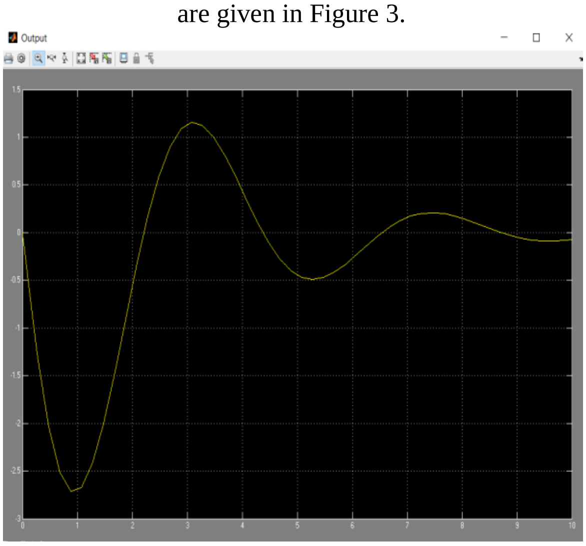

Figure 3: PID Controller Waveform

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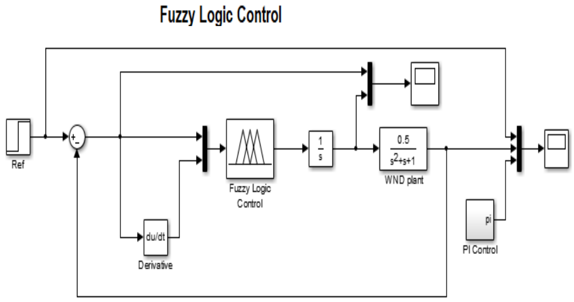

Figure 4: Proposed Fuzzy Logic Controller For Wind Energy

Figure 4 shows the proposed fuzzy logic controlled Wind Energy Conversion system. The output waveform is given in Figure 5 and then tested proposed MPPT is given Figure 6. The waveform for MPPT is given in Figure 7.

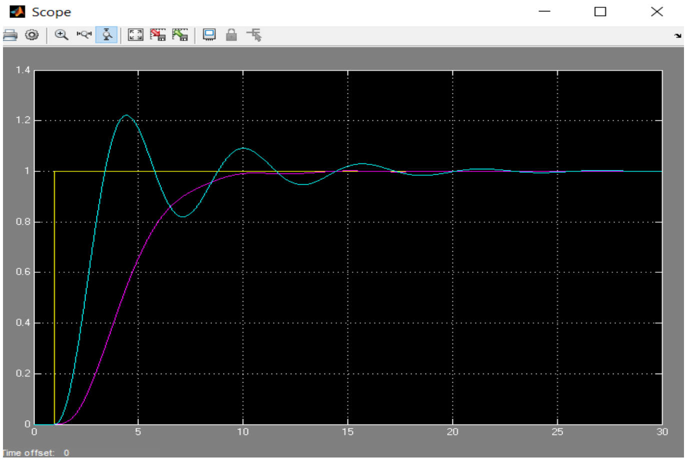

Figure 5: Proposed Fuzzy Logic Controller Waveform

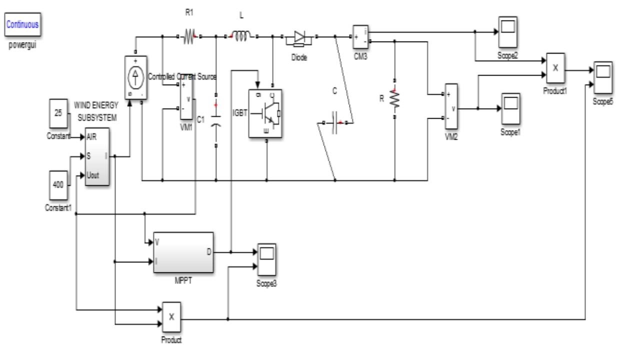

Figure 6: Proposed MPPT in Wind Energy System

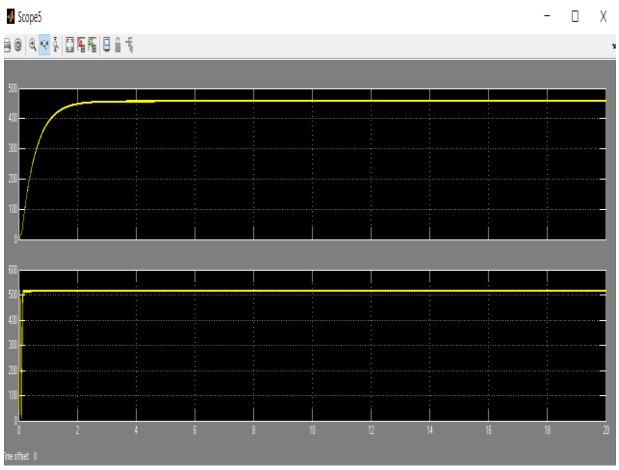

Figure 7: Proposed MPPT Waveform in Wind Energy System

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Table 1: PID Power Generation

PID POWER GENERATION		
INPUT STREAM WIND	OUTPUT TIME STABILITY	EFFICIENCY
1000	9	97%
2000	10.79	98%
500	10	85%
800	8	70%
1500	10	96%

Table 1 gives output time stability in PID Wind Power Generation and Table 2 gives for Fuzzy Logic. Figure 8, 9, 10 and 11 represents improved results in graphs for PID and Fuzzy Logic.

Table 2: Fuzzy Logic Power Generation

FUZZY LOGIC BASED WIND POWER GENERATION		
INPUT STREAM WIND	OUTPUT TIME STABILITY	EFFICIENCY
1000	9.24	97.58%
2000	11	98.36%
500	9.85	85%
800	7.36	70.36%
1500	9.745	96.36%

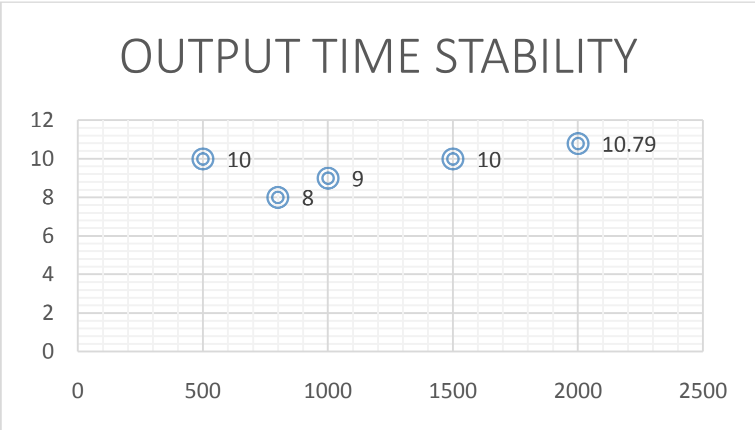

Figure 8: Output time stability PID

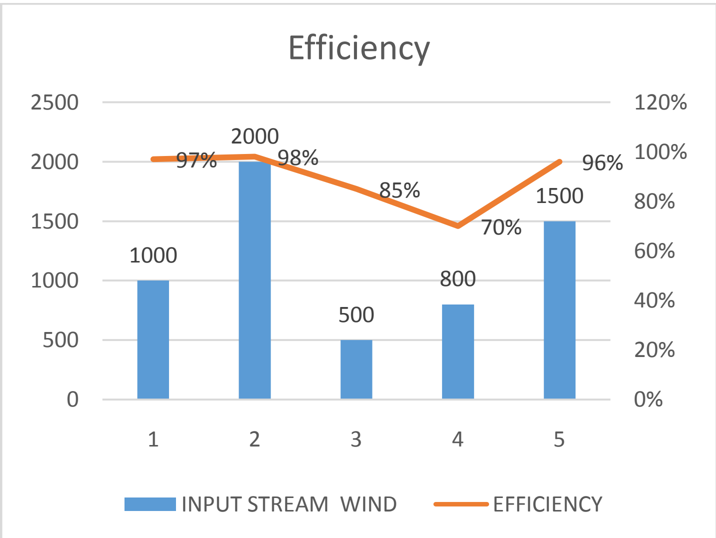

Figure 9: Efficiency PID

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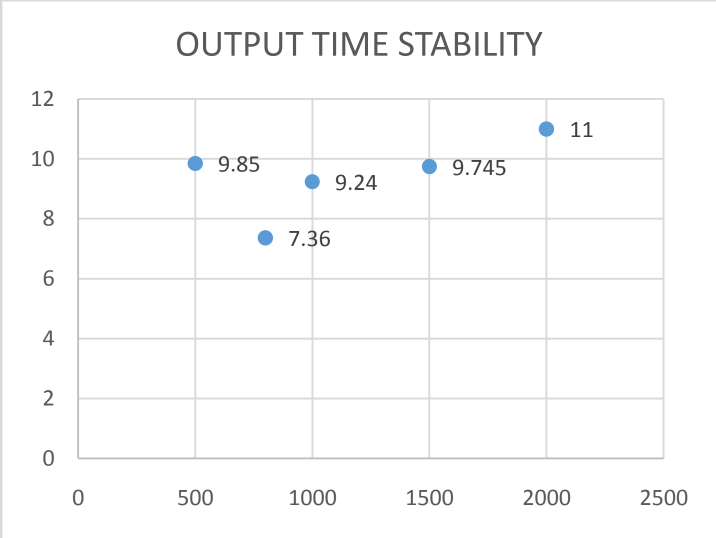

Figure 10: Output time stability Fuzzy

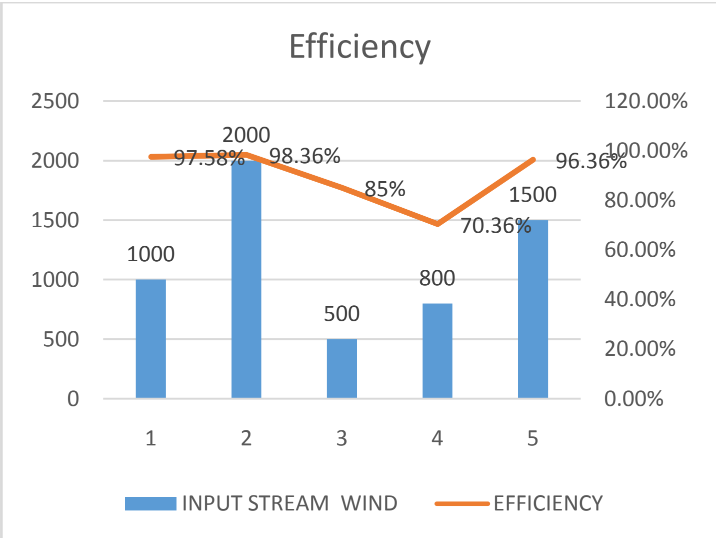

Figure 11: Efficiency Fuzzy

4. CONCLUSION

The simulation of the MPPT technique achieves the maximum power point for wind energy system as well WIND FUZZY system. For a particular irradiance level, maximum power generated by wind generator/WIND FUZZY system is delivered by using MPPT technique at the load. For WIND FUZZY system, perturb and observe MPPT technique is used which works efficiently. For wind energy system, modified perturb and technique adopted from IEEE transactions on energy conversion [6] is used in which with normal wind speed conventional perturb and observe technique is employed and with rapidly wind speed conditions prediction mode is employed. Under rapid wind speed condition, conventional P&O has the direction misleading problems while prediction mode reaches MPP faster. The features of this simulation circuit are: 1) Both renewable sources are stepped up using boost Converter; 2) Different MPPT technique is employed for each source; 3) individual operations are supported. Simulation results are presented in this paper. Converter; 2) Different MPPT technique is employed for each source; 3) individual operations are supported.

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