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Using position control to improve the efficiency of wind turbine

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ABSTRACT

Wind energy is one of the renewable energies that can be using to generate electricity. Increasing demand for this type of renewable energy for sustainability and accessibility. Environmentally as it does not cause any pollution in addition to the abundance of required equipment and less maintenance and long operation life of its parts despite the high cost of the system at its installation but at long term, become cheaper. Wind power generators depend on their operation on wind speed and direction. Therefore, it should be installing in places where the wind speed is adequate and sufficient to rotate its rotor, it knows that wind speed is variable in its speed and direction they change every hour and every season. In this design, many practical and theoretical (simulation) experiments have been done which will be mentioned and explained in details in this research shows that this mechanism raises the efficiency of wind power generators by 80% when the rotor of the wind turbine directed towards the wind than if they were fixed direction.

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1. INTRODUCTION

Clean energy that called renewable energy and there is widespread popular support for using renewable energy, particularly solar and wind energy, which provide electricity without giving rise to any carbon dioxide emissions [1-3]. Utilization of wind energy has increased spectacularly in recent years, with annual increases in installed capacity of around 20% in recent years [4-6]. Research into alternate sources of energy dated back in the late 90s. Electricity can be used onshore and offshore sites to produce from wind with a distinct difference for example in 2015, onshore wind averaged 30% capacity, and offshore 41% [5-7]. The world is growing energy need, alongside increasing population led to the continual use of fossil fuel-based energy sources (coal, oil and gas) which became problematic by creating several challenges such as: depletion of fossil fuel reserves, greenhouse gas emissions and other environmental [7-9]. Wind energy, the emergence of wind as an important source of the World's energy has taken a commanding lead among renewable sources. Wind exists everywhere in the world, in some places with considerable energy density [10-12]. Wind energy harnesses kinetic energy from moving air. The primary application of the importance to climate change mitigation is to produce electricity from large turbines located onshore (land) or offshore (in sea or fresh water) [13-15]. Onshore wind energy technologies are already being manufacture and deployed on large scale [16-18]. Wind turbines convert the energy of wind into electricity. Meeting the needs of the developing world with modern energy and other infrastructure technologies is a critical task for improving quality of life and enhancing human development [19-21]. The wind turbine need the following requirements, previous studies, for the performance improvement of a vertical axis wind turbine, aerodynamic analysis, control mechanism design and its realization of 1kw class model are carrying out. The power output is improving about 60% comparing with VAWT using fixed pitch and symmetric airfoil [22-25].

2. SYSTEM ARCHITECTURE

2.1. Operating principle of the system modeling

The purpose of this research is to design a wind turbine fan rotating system (yaw angle) to make it windward, as shown in red in Figure 1. In order to test the system that has designed in this research and show the effect of wind direction on the efficiency and speed of rotation of the wind turbine fan. A practical experiment has conducted at the wind energy laboratory/energy and renewable energy technology center at the University of Technology/Baghdad. Its purpose is to show how the wind direction affects the rotational speed of the turbine fan. Where a miniature model of a turbine fan has installed, as in Figure 2. A turbine fan has installed on a base that has the ability to change its angle as required. In addition to linking the fan outlet with a rotational speedometer in order to provide the possibility of measuring the fan rotational speed when changing the angle, as shown by the experiment system in Figure 3.

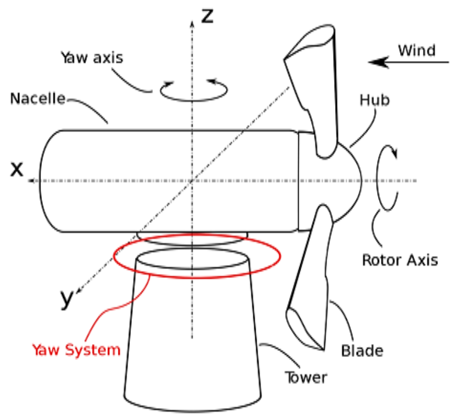

Figure 1. Yaw position control system

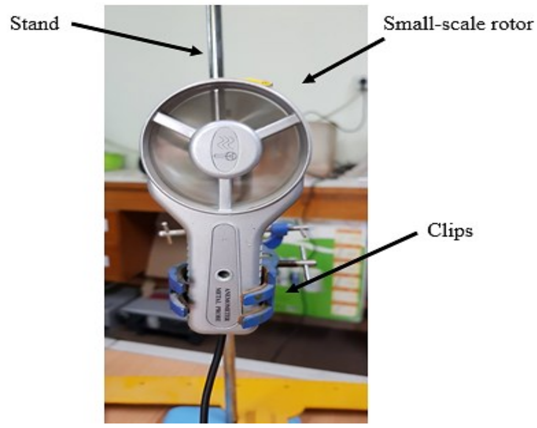

Figure 2. Small-scale wind turbine rotor

Figure 3. Experimental test for the air angel of attack on the rotor

2.2. Proposed experimental and results

This simulation had two experiment include; Experiment one: This experiment shows the effect of changing the angle of wind attack on a wind turbine fan. The test focused on the effect of changing the angle in terms of rotational speed. The rotational speed is very important for generating electricity from wind turbines and raising their efficiency. The higher the wind speed, the faster the rotational speed, and thus the efficiency and the generation of wind turbines are better. Certainly, within the reasonable and permissible limits in terms of design, otherwise at high speed cause the system to collapse. Note that there are many protection systems for wind turbines in cases of high speed during storms. There is no room for this in this research. In this experiment, we considered the zero-degree angle to be the highest wind direction on the turbine fan, while we considered the 90-degree angle as the lowest wind on the turbine. Three values had selected for wind speed: 4 m/s, 3.3 m/s, and 2.6 m s. Table 1 shows the results obtained.

Figure 4 shows the results of the first experiment in the form of curves, through which we can observe the effect of changing the direction of wind on the rotational speed of the wind turbine fan and thus affect its efficiency. From these curves we note that the highest rotational speed when the turbine fan is facing the wind and therefore the highest efficiency and maximum generation are in this case gradually decreasing whenever the wind angle changes until all the curves meet and become zero when you are not facing the wind despite changing the wind speed. Table 2 shows the amount of change of the percentage of the turbine rotation speed when changing the direction of the wind, and therefore the percentage of change of the efficiency of the turbine obtained from the results of Table 1 as the maximum wind impact value is considered to be (100% maximum efficiency, it gradually decreases according to the attack angle of the wind on the fan.

Table 1. Output results of experiment 1

Air angle of attack (Degree)	Wind speed = 4 m/s Turbine Speed (rpm)	Wind speed = 3.3 m/s Turbine Speed (rpm)	Wind speed = 2.6 m/s Turbine Speed (rpm)
0 Max effect	545.672	450.180	354.687
10	511.568	409.254	327.403
20	477.463	388.791	300.120
30	457.000	300.120	259.194
40	368.329	252.373	177.343
50	263.287	218.269	143.239
0	163.701	184.164	114.591
70	111.862	111.862	83.215
80	13.641	6.820	4.092
90 Min effect	6.820	0.00	0.00

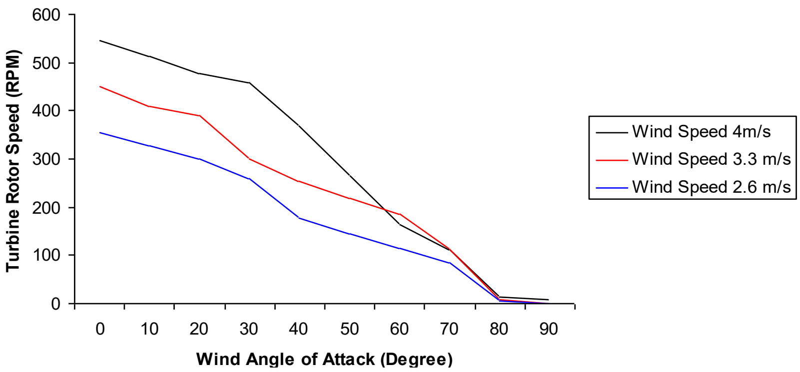

Figure 4. he Wind angle of attack Vs. turbine rotor speed/output results

Table 2. The relation between wind angle and changing of the efficiency according to wind speed

Wind angle of attack (Degree)	Efficiency (%) wind speed 4 m/s	Efficiency (%) wind speed 3.3 m/s	Efficiency (%) wind speed 2.6 m/s
0	100	100	100
10	94	91	93
20	88	87	85
30	84	68	74
40	68	56	50
50	49	49	41
60	30	41	33
70	21	25	24
80	3	2	2
90	2	0	0

Figure 5 shows the curves of changing the efficiency of the turbine relative to changing the angle of the wind attack, and we note that whenever the turbines are facing the wind, they give the highest efficiency, i.e., a direct relationship between them. Wind direction the system rotates the fan towards the wind to avoid low generation efficiency. A control system was designing for the angle intended to rotate the turbine fan-fastening tower, so that it faces winds, Figure 6 showing the box representation of it. This system we note that there are two of the line. It is possible to work with one of them if the line reveals the angle within it. However, it is better to use the two because, through the experiments conducted, it has found that when using two lines as a feedback, the response is better in terms of speed, accuracy, stability and damping of the higher values (damping for the overshoot).

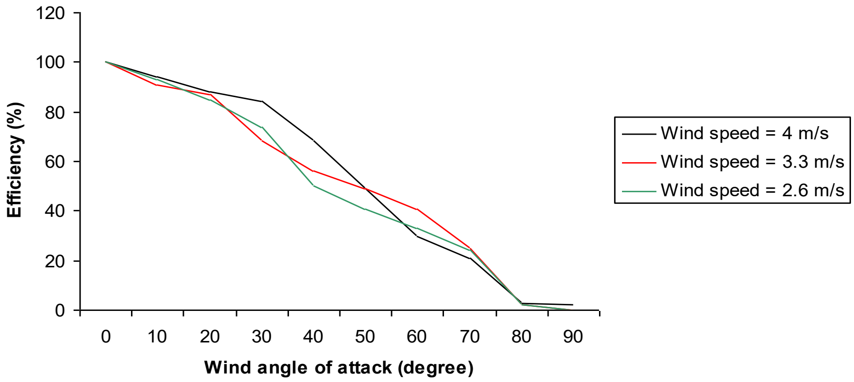

Figure 5. the relation between wind angle of attack and output efficiency for different wind speed

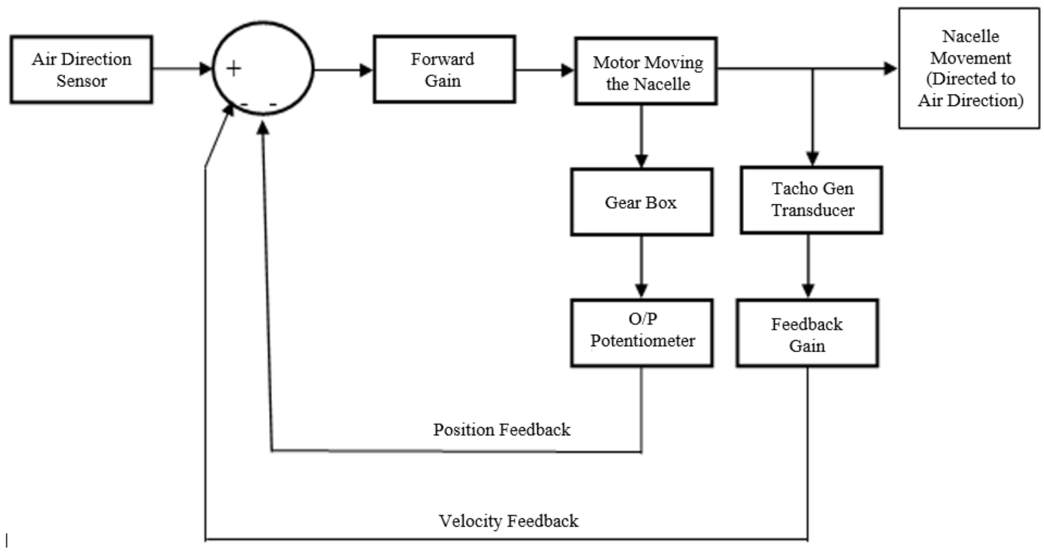

Figure 6. The designed position block diagram

Experiment two : a practical experiment was conducting in the control laboratory in the control and systems engineering department at the University of Technology/Baghdad. To link the control system to the angle, as shown in Figure 7. Where the set value of the system was an electrical signal fed to the system by means of an input potentiometer, which represents the value of the direction of the wind, which comes from the wind direction sensor. As for the output of this system, it is an electrical signal that rotates the tower until the error rate becomes zero between the feed signal and the return signal (set value and feedbacks). Then the system stops rotating, and this represents that the tower has become windward in order to obtain the highest speed and working efficiency of the turbines. The idea of this system depends on the use of potentiometers, which is a resistance of a variable, circular shape that has the ability to rotate by 300 degrees.

Among the characteristics of the rotating resistors that had used in this experiment are the angles gradations on them in degrees, so that any external voltage can read in voltages or degrees as shown in Figure 8. Table 3 shows the practical results of the aforementioned experiment, where the wind attack angle is represented by the value of the output from the input variable (input potentiometer), and the angle of rotation of the tower (yaw angle) is represented by the output voltage (the output angle) of the output variable resistance (output potentiometer). Figure 9 shows the results mentioned in Table 3, in the form of curves.

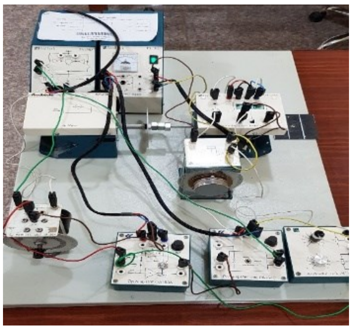

Figure 7. designed position control system experimental work

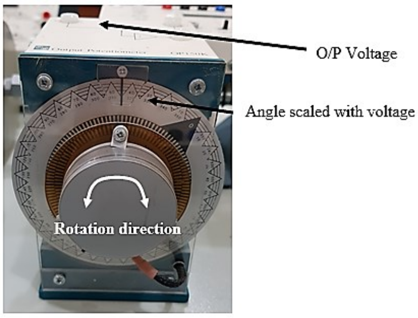

Figure 8. Rotary potentiometers used

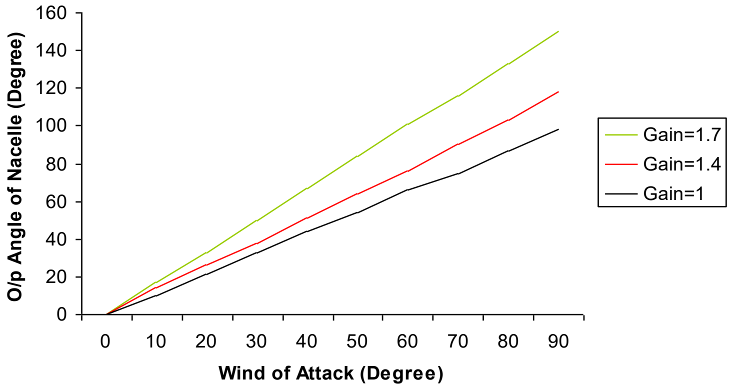

Figure 9. Output results for Table 3

Table 3. Output results for the position control system test

I/P Air Angle of Attack (Degree)	O/P Angle of the Nacelle (Degree) at Gain=1.7 with 1 Feedback	O/P Angle of the Nacelle (Degree) at Gain=1.4 with 1 Feedback	O/P Angle of the Nacelle (Degree) at Gain=1 with 2 Feedback
0	0	0	0
10	17	14	10
20	33	26	21
30	50	38	33
40	67	51	44
50	84	64	54
60	101	76	66
70	116	90	75
80	133	103	87
90	150	118	98

From these curves, it is clear that the Output angle follows the Input angle, taking into account the gain value used (gain). Where I used several values of gain (1, 1.4 and 1.7), where when the input signal is entered a signal is generated that powers the engine. The motor is connecting to a gearbox that rotates the variable resisting output, which in turn gives an electrical signal that is proportional to its rotation angle. It is feeding to the comparator circuit to give an error signal that powers the system until the error signal becomes zero, then the system stops. This response is one of its disadvantages. It is slow for increasing its speed; we either increase the gain value or tie a second return line from the engine. The movement of the engine is converted to an electrical signal by (tacho generator) and fed through the second reflex line to the comparator in order to be compared with the input signal and stop when the error rate becomes zero (the direction of the fan in the direction of the wind).

There is an error rate in these readings due to the accuracy of the reading (readings). Loss of electrical appliances (losses) and accuracy of the devices used (accuracy). In the case of using a single position feedback line, we notice that the response is slow and for increasing the response speed. The second feed line (velocity feedback) has linked, which increases the speed, but we see the status of the overshoot signal in addition to the frequency in the output signal (oscillation), which has reduced by the first feed line. In other words, the two lines of feeding are better to get the better response, even in terms of the error rate in the response, as shown in the attached Table 4 and the curves in Figure 10.

Table 4. Error signal between I/P and O/P signals

I/P Air Angle of Attack	Error of O/P Angle of the Nacelle according to input at G=1.7 with 1 F.B	at G=1.4 with 1 F.B	at Gain=1 with 2 F.B
0	0	0	0
10	0	0	0
20	1	2	1
30	1	4	3
40	1	5	4
50	1	6	4
60	1	8	6
70	3	8	5
80	3	9	7
90	3	8	8

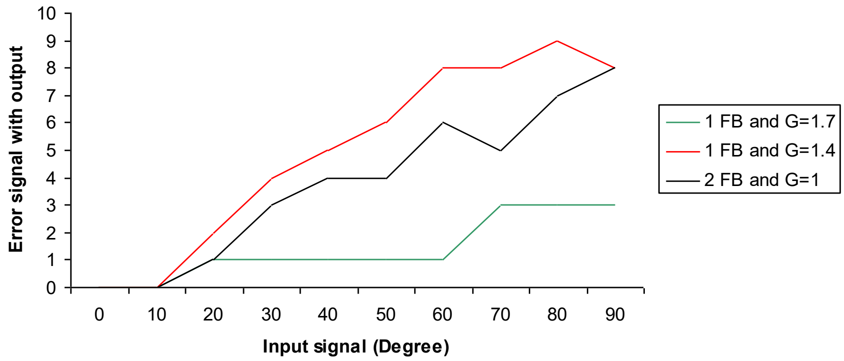

Figure 10. Shows the amount of error between the input signal and the exit signal, and according to the gain values used. Where we note the lowest percentage of errors is at the highest value of the gain and when linking the two feeding lines

3. CONCLUSION

Many studies try to make the turbine rotation speed within the normal limits necessary for its operation and at the same time to protect it from collapse when rotating at high speed due to high wind speed. In this research, a mechanism has been designed to direct the wind energy rotor of the wind turbine to the wind direction when the wind change its direction to increase the rotational speed in order to increase the efficiency of generating electric power and certainly within the limits allowed. The results in this work shows that this mechanism raises the efficiency of wind power generators by 80% when the rotor of the wind turbine directed towards the wind than if they had fixed direction.

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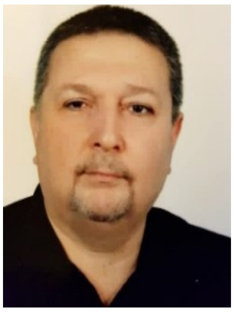

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