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# PLANETARY GEARBOX AND SPACING BETWEEN TWO SETS OF BLADES TO INCREASE PERFORMANCE EFFICIENCY FOR MANUFACTURED DUAL SMALL WIND TURBINE

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**Abstract**

Energy is one of the essential and main challenges facing our society today, for this, the wind turbine industry became one of the best choices for the production of energy among all energy sources. In modern time wind power technology has become the most established sources in generating the electricity due to its promising technical advantages besides the significance of producing electrical energy based on wind turbine with single rotor, as well as wind turbine with dual rotor. Design and manufacturing of turbine system functioning in two previous categories are required. They have benefits for increasing a generation of electricity. The goal of this research article is to produce electricity under the wind speed to 1m/s or greater. Headed for achieving this, wind speed as well as wind direction have been employed based on obtained data from Zerbatiya Station in Iraq. A simulation has been employed for generating rotational speed from 1 to 13m/s designed for front and rear blades. Change the distance between the rotor blades in the manufactured system for the purpose of studying the effect of changeable distance of the blades on power generation. The following were added to the system: Provision the dual small wind turbine with two types of gearboxes. The first type of gearbox connects the two rotors (front and rear parts) this will increase torque and reduce the rotational speed. The second type of gearbox named planetary is placed before the permanent magnet synchronous generator, this will reduce the torque and increase the rotational speed. The manufactured system has been tested practically in all the cases mentioned in the research. For the purpose of reducing the mechanical vibrations and friction of the system, passive magnetic bearing supports had been used. Genetic Algorithm (GA) has been employed in a simulator for attaining the optimal generated electrical energy. This study determines the finest blades position at diverse speeds for generating electrical energy based on Permanent Magnetic Synchronous Generator (400 W). The highest produced power in a dual wind turbine (DWT) in a case of rotating rear and front blades in identical direction has been gotten under 151 rpm. A spacing of 7 cm can be better in power generating of 103.614 W.

Keywords: Blades spacing, Dual wind turbine, Genetic algorithm, Planetary gearbox.

## 1. Introduction

The advantages of the Dual Wind Turbine (DWT) structure to the gearbox are highlighted, by dividing the high power into two parts and input at the same time, the transmission torque and forces of gears and their bearings are effectively decreased, and the service life of the bearing is enhanced [1].

Sutikno, P.; and Saepudin [2] designed a Contra Rotation Double Rotor Wind Turbine (CR-DRWT), composed of small-sized rear wind and large-sized front wind rotor at the same side. The (CR-DRWT) depend on the wind speed. Because the (CR-DRWT) has contra rotation rotor, so it can rotate relatively on adequate rpm, at moderate wind speed. The relative rotational speed remains constant, when the wind speed increased, even at high wind speed, it remains constant, the rear rotor is rotate by the front rotor and rotated at same direction. This class of wind turbine takes self-regulating characteristics in terms of speed as a result of a variance in torque amid dual stages of horizontal axis wind turbine.

Wang et al. [3] proposed new projected dual rotor wind turbines (DRWT) for mitigating the losses through presenting a different rotor. This design has been capable of harnessing additional wind energy through reducing root loss in roots area of a main rotor blades under similar airflow.

Luo and Niu [4] investigated the experimental aeromechanics and the features of DRWTs in a counter-rotating or co-rotating structure that compared with conservative SRWT model demonstrating elementary physics for optimizing the wind turbine designing with the intention of increasing energy productivity with finest durability.

Ozaby et al. [5] have shown that the effective correlation has been amid air stream speed and power. Although specified values of angles for rotors as well influenced productive power, there has not been any detected consequence in distance changes among rotors. Field investigations have validated outcomes as well as remarks about wind tunnel.

Romański et al. [6] presented a dual wind small turbine based on the device for reversing a rotor rotation for studying several cases and achieving the finest consequences with a separation mechanism and reformed a planetary gear box that can be appropriate for machine tool use.

Khalifa et al. [7] designed small (DWT), which uses a device that makes the rotor rotate in a reverse direction to study a variety of situations to obtain the optimal outcomes and efficiency of the separation mechanism.

Sultan et al. [8] designed a gearbox of dual rotor wind turbine by using Computer Aided Three-Dimensional Interactive Application (CATIA) software for the gearbox design, the gear dimensions are calculated more accurately by basic formulae. The gearbox contains two input shafts and one output shaft. Double rotors in the front and back side pick-up wind energy.

Jauregui et al. [9] presented the application of a genetic algorithm to optimize the dynamic response of a gearbox. Optimization takes into account the principal parameters which influence overlapping excitation frequencies (resonances) and therefore, minimize vibrations caused by the interaction among the gearbox elements.

Nandeppagoudar et al. [10] showed a space and load limits stand for the major purposes. Based on the investigational consequences, it has been realized that big reduction ratio 90.8 has been accomplished in dual stages for planetary gearbox that has been in 3 stage planetary gearbox.

This paper shows the manufactured dual small wind turbine with the effect of using planetary gearbox and adjustable distance between two sets of (DWT) during rotating in the one direction (same) and reverse directions to produce the best value of power generation by Genetic Algorithm (GA) method.

## 2. Investigation of Produced Power Based on Dual Wind Turbine

Based on Betz principle, the highest wind power has been closely 16/27 of an available energy in the wind. On the other hand, lower wind axial speed is noticed through two-thirds by the singular rotor disc. So forth, processing wind turbines can be done by converting less than forty percent of wind energy to electricity. As rotation behind 1st rotor can be rotated in a reversed path to a rotor direction. The productivity of power for a turbine rotor as shown in Eq. (1) and the wind kinetic energy for each unit time have been specified along these lines as shown in Eq. (2) [11].

$$P_T = T_m . \omega \tag{1}$$

$$P_W = \frac{1}{2}\ \rho V_o^3 A \tag{2}$$

where $A$= Swept area of the blades ($m^2$), $P_T$= Output power from a turbine rotor (W), $P_W$= Wind kinetic energy per unit time (W), $T_m$ = Mechanical torque at the turbine side (N.m), $V_o$= Wind velocity (m/s), $\rho$ = Air density at the hub height ($kg/m^3$) and $\omega$=Angular velocity (rad/s).

This constraint has been identified as the Betz limit. Consequently, a highest power based on turbine output can be stated as below Eq. (3).

$$P_W = \frac{1}{2}\frac{16}{27}\ \rho V_o^3 A \tag{3}$$

A rotor power coefficient $C_p$ can be expressed as a relation of an output power for a rotor to wind power as exposed in Eq. (4).

$$C_P = \frac{\text{Actual Electrical Power Produced}}{\text{Wind Power into Turbine}}$$

$$C_P = \frac{P_T}{P_W} = \frac{T_m.\omega}{\frac{1}{2}\rho V_o^3 A} \tag{4}$$

$$\lambda = \frac{V_{Tip}}{V_0} = \frac{R.\omega}{V_0} \tag{5}$$

where λ is the speed ratio of blade tip [12].

## 3. Practical Section

Here, we will clarify the applied characteristic of manufacture of the wind power structure based on single and dual wind turbine blades. They involve diverse states of secondary processes. The practical work is subdivided into 3 foremost subdivisions of mechanical, electrical and control subdivisions of an entire system with extracting all the desired values.

### 3.1. Mechanical constituents

Mechanical constituents are grouped into three sections. First section stands for the front section to be positioned in an expected wind direction. Second section, as presented in Fig. 1 stands for a rear direction and third section is represented by a gearbox and 3-phase permanent magnet synchronous generator. Rear and front sections are subdivided into movable wing as well as non-movable wing.

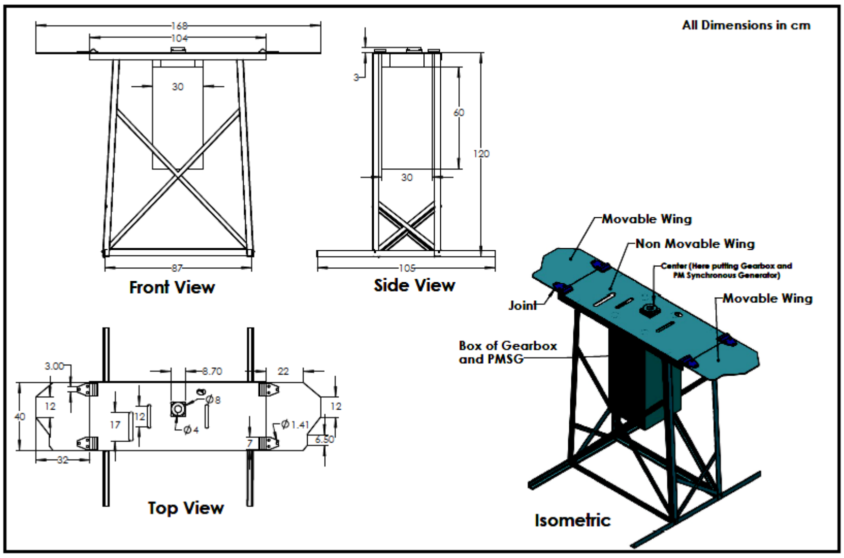



**Fig. 1. The base structure of the manufactured (DWT).**

#### 3.1.1. Front section

**(a) Movable Wing**

A movable wing has been a significant issue for the reason that it has an innovative impression in this study, it has: i-Blades set has three blades for every Model (NE-M3). A full diameter has been around (165 cm) manufactured from (PVC) as shown in Fig. 2(a) with a hub in which blades have been employed as depicted in Fig. 2(b). The blade tip thickness of the side profile has been 4 mm to 3 mm.


**Fig. 2. Blades of wind turbine adopted in this study (a) blade front view, (b) the blades hub.**

(i) A movable wing base with (32 cm×40 cm×0.4 cm) dimensions. (ii) Figure 3 clarifies everything related to (iii) to (v). Double ball bearing, model P205, inner diameter of 25 mm, W / Grease Zerk. Pillow based on a base made of Al. (iv) The shaft length of 575 mm is divided into three parts with diameters (16 mm, 25 mm and 28 mm). (v) Because of the double joints, the movable wings are equipped with front and rear non-movable wings. Based on huge tolerances and durability of lifting movable parts, they are inclusive and flexible.

All components shown in Fig. 3 are: (1) blade, (2) blade hub, (3) bushing, (4) ball bearing with $d_{in}$ = 0.025 m, (5) journal, (6) wing base, (7) ) Lifting arm, (8) joint, (9) slotted hollow shaft, (10) universal joint, (11) ball bearing with $d_{in}$= 0.020 m (12) simulator motor.


**Fig. 3. The movable wing.**

**(b) Non movable wing**

The wing volume is about 832 $cm^3$. As depicted in Fig. 4, involves the subsequent constituents:

(i) Pair kinds of ball bearings in which about 20 mm. The first kind be used for supported rear shafts along with a horizontal front, while the second kind of ball bearing can be used in supporting the gearbox shaft.

(ii) Shaft of 410 mm length with 20 mm diameter has been produced from iron.

### 3.1.2. Rear section

**(a) Movable wing**

It involves the subsequent constituents:

(i) The symmetric blades collections with a front section.

(ii) Hub based on carried blades. They are feasibly constricted based on the following: A case that matches the angles among the rear and front sections. Another case is the deviation among blades of the rear and front sections. Each component of this part has been analogous to the previous mentioned contexts in a front section.

**(b) Non movable wing**

A shaft end of front set and a rear shaft includes gear using (helical) type with (15) teeth in which inner diameter has been (16 mm) as illustrated in Figs. 4. and 5 explains the dual gears that have given motion for horizontal gear with (33) teeth, inner diameter of (20 mm) and (low carbon steel) material. It has been associated with the vertical shaft using a full dimension of 225 mm. Some components shown in Fig. 5 are: (1) mechanism for lifting the movable wings, (2) ATV buggy reverse gear and (3) starter motor. The small flywheel for supporting the starter motor was used to increase the internal torque for the purpose of increasing rotation .

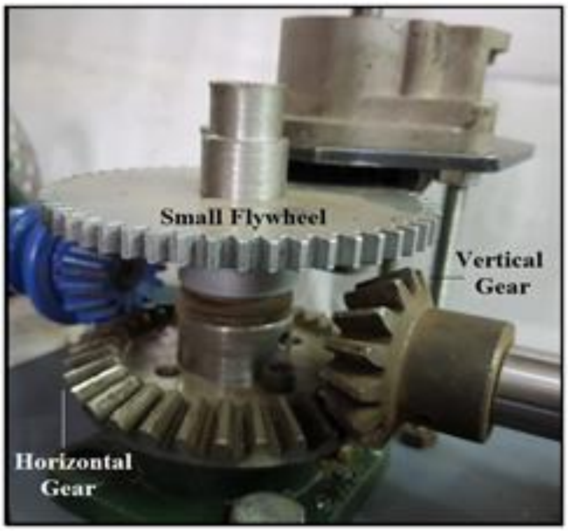



**Fig. 4. Bevel gears used in this work.**

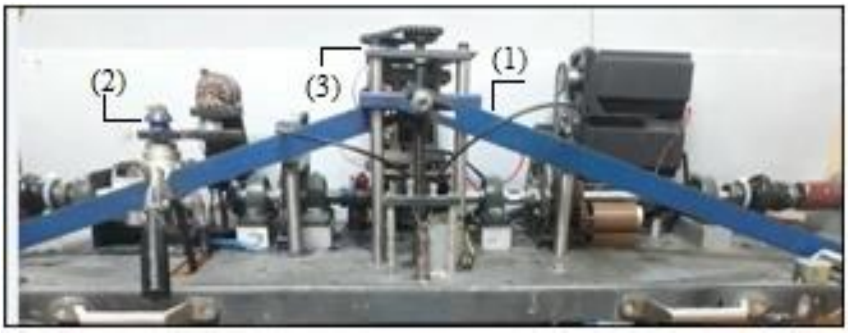



**Fig. 5. A side view of some components of the manufactured system.**

The non-movable wing has the subsequent elements: i- Dual ball bearing in which the internal diameter has been (20 mm) with made aluminium bases of 148.48 $cm^3$ volume. ii- A full splined shaft length of 210 mm, with 4 parts of (16, 20, 21 and 16 mm) diameters. iii- Gear in which a rotor (journal) is connected for a rear section with a central system gear using (15) teeth, (Steel) material with (16 mm) inner diameter.

### 3.1.3. Planetary gearbox

This part has been placed at the bottom of dual wind turbine manufactured as shown in Fig. 1 there are also other components attached to this part. Planetary gearbox advantages include the coaxial arrangement of the input shaft and the output shaft, the load distribution of multiple planetary gears, the high efficiency brought by the low rolling power, and the almost limitless transmission ratio selection because of combination of multiple planetary gear sets.

This part includes mechanical components such as gearbox, other accessories and electric components such as permanent magnet synchronous generator. Using the gearbox in the machines for the purpose of increasing the rotary torque and reducing the rotation speed but in the manufactured dual wind turbine there is a need for a high rotational speed and high torque must be provided for the purpose of obtaining good performance. For the purpose of achieving this goal planetary gearbox has been used as shown in Figs. 6 and 7.

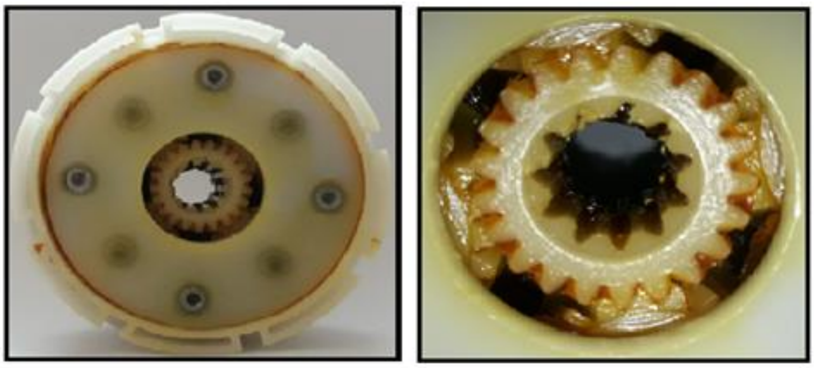
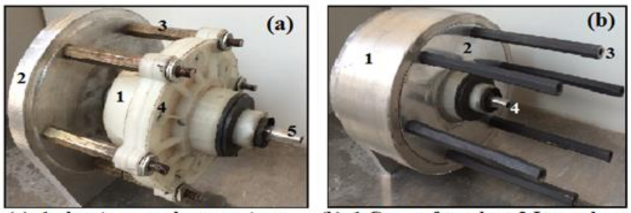


**Fig. 6. Planetary gearbox type used in this work.**

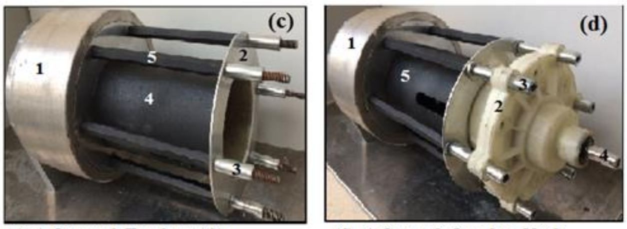
Reduction ratio for this type of planetary gearbox is 4.25:1 for one stage (the type of gear in the gearbox is helical gear ), (Model Number NPTC-GB-036), in this work 2-stage of the gearbox has been designed the as shown in Figs. 7(a)-(e). It is possible to develop the planetary gearbox to be 3- stage instead of 2-stage but need increasing in the rotational torque.

Figure 8 shows the structure diagram that the following parts are manufactured: the base, all the components on it and the components below. When the system is operating in the same or reverse direction, the upper gearbox remains rotate in one direction by using ATV-Buggy reverse gearbox as shown in Fig. 9. Two mechanical brakes were used one for the front rotor and the other for the rear rotor for the purpose of stopping the rotors.



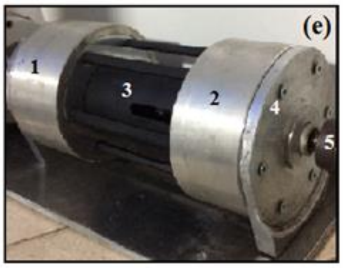

(a)- 1-planetary gearbox one stage; 2- Top base;3-Hexagonal screw; 4-Hollow; 5- Output shaft and 6-Inlet shaft

(b). 1-Cover of gearbox; 2-Lower base; 3- Rods to foundation and 4-Output shaft




(c). 1-Cover; 2-Top base (2); 3-Bolts; 4-Cover and 5-Rods

(d). 1-Cover;2-Gearbox No.2; 3-Nuts; 4-Output shaft No.2 and 5- Cover




(e).1-Top cover; 2-Lower cover; 3-Cover between two gearbox; 4-Lower base and 5-Output shaft

**Fig. 7. Installation steps of planetary gearbox**

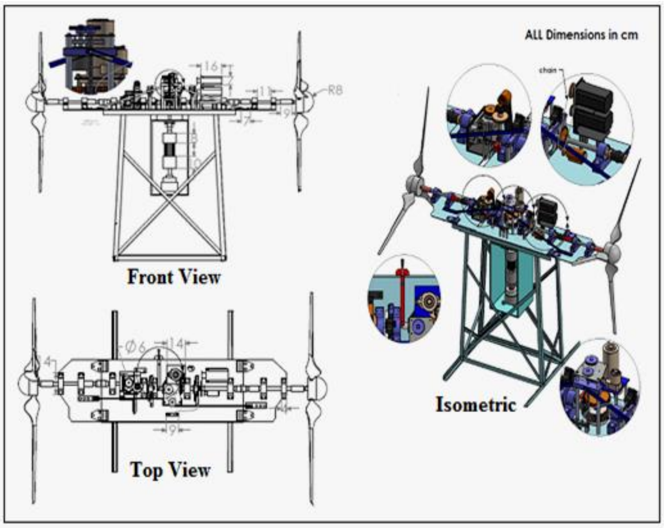



**Fig. 8. The installation of mechanical parts**

**Fig. 9. ATV-Buggy reverse gearbox, model ATV 009-Sophie.**

## 3.2. Electrical components

### 3.2.1. Three-phase permanent magnet synchronous generator (PMSG)

A difference between a wound field synchronous generator and permanent magnet synchronous generator has been that the first one needs DC current for exciting a rotor winding. This excitation has been accomplished based on slip rings and brushes on a generator shaft. Nevertheless, there have been numerous drawbacks as in demanding systematic preservation and carbon dust cleaning. While in the second one, an exciting field has produced based on permanent magnets in a rotor. They are normally employed for converting a mechanical output power of wind turbines into electrical power of a grid. Figure 10 shows the permanent magnet synchronous generator used in this work.

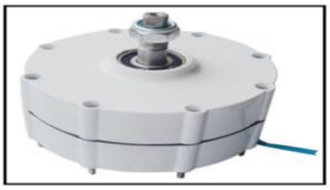


**Fig. 10. Permanent magnet synchronous generator of dual wind turbine.**

### 3.2.2. Motor speed measuring (sensor module Lm393)

Checking the rate of electric motor is the major goal of this sensor as shown in Fig. 11. This module can be utilized in association with a microcontroller for the detection of the motor speed, pulse count and limit of position. Four speed sensors were used in different parts of the system manufactured in this work and are as follows: The first at the beginning of the front rotor, the second in the rear rotor, the third before gearbox and the fourth after this gearbox.

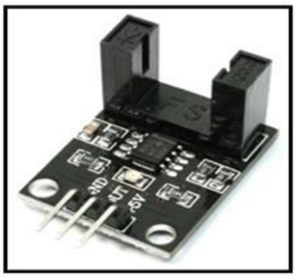


**Fig. 11. Sensor module Lm393**.

### 3.2.3. Stepper motor

A stepper motor as shown in Fig. 12 which has no brushes, is a synchronous electric motor which transforms the digital pulses to the mechanical shaft rotation. Its operation depends on the 200 discrete steps (all of same size), which represents one period, then the stepper motor will sent separate pulse to each step, while the motor takes only one step at a time, then each pulse will cause the motor to rotate to accurate angle, typically 1.8°, so that the control of the position of the motor will be done without needing for any feedback. The increased digital pulses in frequency will change the movement of the steps to a continuous rotation. with the rotational speed which is proportional with the frequency of pulses.

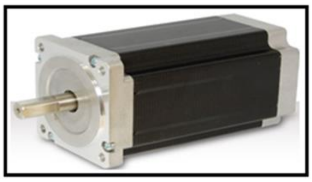


**Fig. 12. Stepper motor.**

## 4. Control Circuit of The Dual Wind Turbine

Figure 13 shows the electrical circuit of the manufactured system (DRWT), where it is equipped with electrical power (220V) for the purpose of feeding the part of the simulation system through the power supply (80Vdc).All components shown in Fig. 13 are: (1) power supply (12Vdc), (2) power supply (80Vdc), (3) micro stepping driver, (4)stepper motor, (5)square wave generator (signal generator PWM LCD Display (12477)), (6) Arduino mega 2560, (7) speed sensor, (8)speed adjust DC motors, (9) L298N (5V, 12V) dual motor controller, (10)brake DC motor, (11) anemometer, (12)reverse DC motor,(13) 10KΩ potentiometer, (14)self-starting motor, (15)relay (12V),(16) permanent magnet synchronous generator,(17) charge controller,(18)ACS712 current sensor (5V), (19) 12V dc battery, (20) external load.

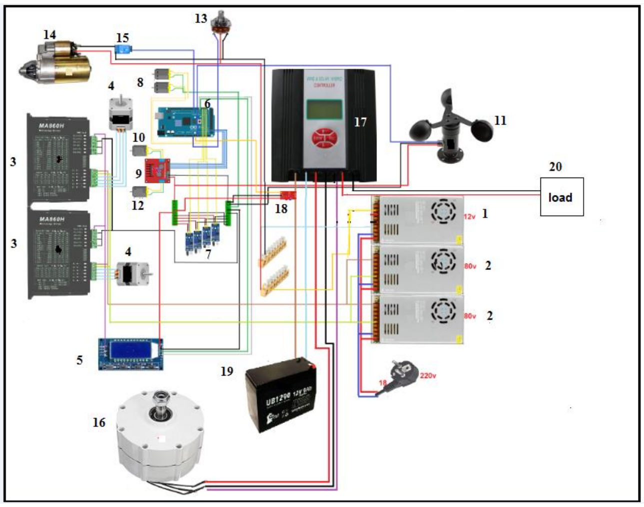



**Fig. 13. Control circuit of the dual wind turbine.**

## 5. Results and Discussion

### 5.1. Production of wind speed based on simulation motor

Simulations are done for simulating an operative fabricated system in each investigated cases employing the stepper motor. Stepper motor rotates a front rotor. Therefore, a system can be rotated similarly to that occurs in the existence of natural wind. A foremost objective of this structure is for taking the wind energy benefit for wind speed ranging from (1 to 2m/s) or higher. As depicted in Table 1 with the intention of ensuring the typical simulation operation, the motor speed has been altered for suiting a wind velocity (1-13 m/s).

**Table 1. The influence of simulating motor speeds on (DWT).**

| No. | Motor speed (rpm) | Wind speed m/s |
|---|---|---|
| **1** | 11 | 0.950 |
| **2** | 13 | 1.123 |
| **3** | 16 | 1.382 |
| **4** | 18 | 1.555 |
| **5** | 20 | 1.727 |
| **6** | 23 | 1.987 |
| **7** | 25 | 2.159 |
| **8** | 27 | 2.332 |
| **9** | 29 | 2.505 |
| **10** | 32 | 2.764 |
| **11** | 34 | 2.937 |
| **12** | 36 | 3.110 |
| **13** | 39 | 3.369 |
| **14** | 41 | 3.542 |
| **15** | 48 | 4.146 |
| **16** | 52 | 4.492 |
| **17** | 59 | 5.097 |
| **18** | 71 | 6.133 |
| **19** | 82 | 7.084 |
| **20** | 93 | 8.034 |
| **21** | 105 | 9.071 |
| **22** | 116 | 10.021 |
| **23** | **128** | **11.058** |
| **24** | **139** | **12.008** |
| **25** | **151** | **13.045** |

In Table 2, it is assumed that the speed of the front rotor rotation is less than the speed of the rear rotor because the mechanical energy exerted on the system for the purpose of rotation comes from the front rotor and therefore a rotary torque will be generated in the upper gearbox. This leads to rotating of rear rotor gear in a higher speed (gear ratio).

Table 2 shows there are rotational speed sensors, sensor no. (1) for front rotor, sensor no. (4) for rear rotor and sensors no. (2) and no.(3), both located before and after the gearbox type planetary, respectively. When reading these values it is clear that the speed measured in sensor no. (2) is the lowest speed in the manufactured system this is due to the use of upper gearbox in which the input speed is from the front and rear rotors, for example, when the speed of front rotor is 11 rpm the rear rotor will rotate at 20 rpm while output will be 5 rpm. This indicates that the upper gearbox was used to reduces the rotational speed and increase angular torque. The sensor no. (3) reading (after two stage planetary gearbox) was 89 rpm, which means that this gearbox was used to reduce torque and increase the percentage of rotation by 1:4.25 for each stage. All results of the wind power generation through theoretical analysis are mentioned in [ 11].

**Table 2. Effect of simulation motor speeds on the front and rear rotors.**

| No. | Rotational Speed of Motor | Front Rotor Sensor No. 1 | Rear Rotor Sensor No. 4 (rpm) | Increase Speed | Sensor No. 2 (rpm) | Sensor No. 3 (rpm) |
|---|---|---|---|---|---|---|
| **1** | **11** | 11 | 20 | **1.818** | 5 | 89 |
| **2** | **13** | 13 | 24 | **1.846** | 6 | 106 |
| **3** | **16** | 16 | 27 | **1.687** | 7 | 128 |
| **4** | **18** | 18 | 32 | **1.777** | 8 | 145 |
| **5** | **20** | 20 | 34 | **1.700** | 9 | 162 |
| **6** | **23** | 23 | 39 | **1.695** | 10 | 187 |
| **7** | **25** | 25 | 44 | **1.760** | 11 | 204 |
| **8** | **27** | 27 | 46 | **1.703** | 12 | 217 |
| **9** | **29** | 29 | 51 | **1.758** | 13 | 234 |
| **10** | **32** | 32 | 56 | **1.750** | 14 | 259 |
| **11** | **34** | 34 | 58 | **1.705** | 15 | 276 |
| **12** | **36** | 36 | 63 | **1.750** | 16 | 289 |
| **13** | **128** | 128 | 222 | **1.734** | 56 | 1033 |
| **14** | **139** | 139 | 242 | **1.741** | 61 | 1122 |
| **15** | **151** | 151 | 261 | **1.728** | 66 | 1220 |

## 5.2. Single wind turbine

At which time the wind turbine scheme has constructed, it must be located in the projected wind path based on details provided by meteorological department. Table 3 displays in depth the single-rotation wind turbine operation as a simulated speed is ranged from lower one m/s. to thirteen meter per sec. A stepper motor can be employed in simulation to be operated in the pulse mode. Namely, as a measured speed has been 11 rpm, a system can provide the real number of evaluations about current, voltages in addition to the produced electrical energy. Visual studio 2015 simulator has been employed for this purpose based on genetic algorithms to get the finest real generation magnitudes. Headed for illustrating the significance of changing the values of generated power, Table 4 gives in details the actual magnitudes as well as the Genetic Algorithm (GA) about the currents, powers, and voltages. Figure 14 explains three curve results about the highest magnitudes and minimum magnitudes created throughout the system operation. The produced power during computing through GA values has been restricted by these magnitudes. The results obtained by using planetary gearbox differ from the results in [8], because of the size of sun gear, number of planet gears and number of stages.

**Table 3. All results from operation of single wind turbine.**

| Simulation | | Actual Values | | | Genetic Algorithm (GA) | | |
|---|---|---|---|---|---|---|---|
| **Front Rotor Speed** | **Wind Speed (m/sec)** | **Voltages (Volt)** | **Current (A)** | **Power (W)** | **Volt. (Volt)** | **Current (A)** | **Power (W)** |
| **11** | **0.950**<br>**0.950** | **12.41**<br>**12.25** | **0.224**<br>**0.215** | **2.784**<br>**2.634** | 12.51 | 0.222 | 2.778 |
| **13** | **1.123**<br>**1.123** | **12.41**<br>**12.2** | **0.276**<br>**0.262** | **3.428**<br>**3.201** | 12.36 | 0.273 | 3.380 |
| **16** | **1.382**<br>**1.382** | **12.25**<br>**12.05** | **0.346**<br>**0.289** | **4.248**<br>**3.482** | 12.25 | 0.333 | 4.081 |
| **18** | **1.555**<br>**1.555** | **12.2**<br>**11.9** | **0.355**<br>**0.332** | **4.339**<br>**3.960** | 12.20 | 0.336 | 4.106 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **20** | **1.727**<br>**1.727** | **12.2**<br>**11.85** | **0.403**<br>**0.391** | **4.925**<br>**4.633** | 12.20 | 0.403 | 4.925 |
| **23** | **1.987**<br>**1.987** | **12.15**<br>**12.25** | **0.488**<br>**0.444** | **5.938**<br>**5.448** | 12.15 | 0.4545 | 5.522 |
| **25** | **2.159**<br>**2.159** | **12.2**<br>**12** | **0.510**<br>**0.494** | **6.222**<br>**5.928** | 12.10 | 0.499 | 6.042 |
| **151** | **13.045**<br>**13.045** | **13.06**<br>**12.96** | **6.642**<br>**5.422** | **86.745**<br>**70.279** | 13.01 | 6.289 | 81.821 |

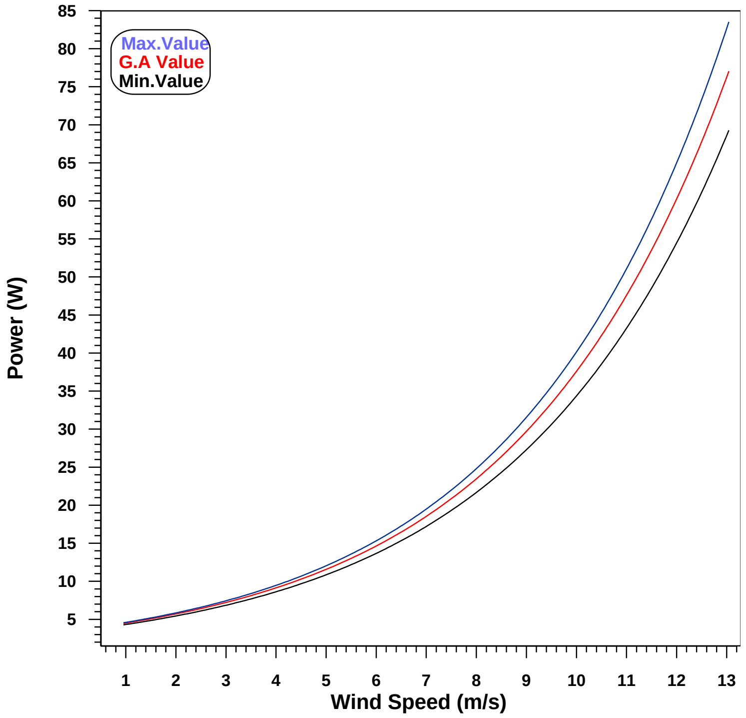



**Fig. 14. Electrical produced at variable linear W.S.**

### 5.3. Effect of the adjusted distance between two sets of dual wind turbine

This case will recognize the effect of changing the distance between the front and rear blades, this case includes the first normal distance (the distance equal 0) and the second when the distance change 7 cm from each side as shown in Fig. 13 with a change in the direction of rotation blades as follows:

#### 5.3.1. Rotation in the same direction

Table 4 shows the amount of change in electric power generated when the distance between the front and rear blades changes. It was found that when the rotational speed is more than 100 rpm the spacing of 7 cm will be better in power generation as shown in Fig. 15 but there is an important note that this spacing will lead to the generation of (i) mechanical vibration in the system and that has been treated by increasing the damping of the manufactured system and (ii) more power. The increase in energy generation occurs in the case of increasing the distance between the front and rear blades for the two reasons: the first increase the length of the rotor leads to increase rotational torque and secondly reduce the resistance of the impact of the system's cover on the attack of wind swirls.


**Fig. 15. The distance between the front and rear blades changing about 7 cm.**

**Table 4. Effect of the adjusted distance when rotating in the same direction.**

| Simulation | | Power Generated | |
|---|---|---|---|
| **Rotor Speed (rpm)** | **W.S (m/s)** | **Distance (0)** | **Distance (7 cm)** |
| 11 | 0.950 | 2.892 | 2.577 |
| 25 | 2.159 | 6.052 | 5.581 |
| 36 | 3.110 | 8.679 | 7.903 |
| 48 | 4.146 | 11.645 | 10.929 |
| 59 | 5.097 | 14.129 | 13.536 |
| 71 | 6.133 | 17.118 | 16.223 |
| 82 | 7.084 | 19.637 | 18.746 |
| 93 | 8.034 | 22.716 | 21.336 |
| 105 | 9.071 | 25.860 | 25.976 |
| 116 | 10.021 | 33.681 | 35.102 |
| 128 | 11.058 | 49.142 | 55.380 |
| 139 | 12.008 | 66.334 | 78.564 |
| 151 | 13.045 | 87.498 | 103.614 |

### 5.3.2. Rotation in the reverse directions

Table 5 shows the effect of the change in spacing between the front and rear sets. It was found that the spacing is useful for increasing the power generated when increasing the rotational speed. There is less stability than the previous case and this was noted from the work of the system.

**Table 5. Effect of the adjusted distance when rotating in the reverse directions.**

| Simulation | | Power Generated | |
|---|---|---|---|
| **Rotational speed of front rotor (rpm)** | **Wind speed (m/s)** | **Distance (0)** | **Distance (7 cm)** |
| **11** | **0.950** | 2.623 | 2.338 |
| **25** | **2.159** | 6.052 | 5.250 |
| **36** | **3.110** | 8.656 | 7.560 |
| **71** | **6.133** | 17.118 | 16.043 |
| **82** | **7.084** | 19.770 | 18.164 |
| **93** | **8.034** | 19.374 | 20.930 |
| **105** | **9.071** | 22.959 | 51.761 |
| **139** | **12.008** | 63.196 | 77.644 |
| **151** | **13.045** | 81.404 | 92.628 |

## 6. Conclusions

The conclusions of this work are:

- The speed of rotation of the front rotor corresponds to the speed of rotation of the simulator. This is evident from the reading of sensor number 1, but the rear rotor rotates more rapidly. This is due to the size of the gears for the rotational movement located after the upper gearbox in the rear part this increase ranging from (1.7 -1.846).
- The operation of the (SWT) will produce a small amount of ability at one meter per second., but this power will be multiplied at a speed of 2 m/s. GA value is considered the best value which is 81.821W at 151 rpm. An upper gearbox is used to increase the torque and the two-stage planetary gearbox is used to increase the rotational speed.
- The amount of change in electric power generated when the distance between the front and rear blades changes. It was found that when the rotational speed is more than 100 rpm the spacing of 7 cm will be better in power generation.
- Rotating of dual wind turbine in the same direction is better than opposite direction to generate electricity.
- For the purpose of reducing the mechanical vibrations of the system, passive magnetic bearing supports have been used, which have high magnetic forces as well as high rotational torque, and thus the vibrations will be reduced. Also, rubber dampers were used in the places where the parts of the system were installed.

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