



Experimented Examination of Power Produced for Dual Rotor Wind Turbine over Single Rotor Wind Turbine

Vinay Mishra , H.K.Paliwal

Abstract: As that wind energy is the vital energy resource which can be used widely to facilitate humane being prolong till the time nature or so called wind is there main aim of this paper is increase extraction percentage of energy from wind using dual rotor wind turbine connected on same axis, analysis were carried out experimentally for the increased power coefficient C_p . It has been compared and found that with respect to single rotor or turbine dual wind power is having larger value of C_p and torque, moreover instead of using one turbine for two turbine on same axis the value of C_p increases with the better balancing stability, further the comparison is made with the performance of single bare wind turbine. Compare to that of single rotor if we used two rotor on same shaft then the torque and power increases on the other hand we will also get large stability due to weight balance condition and was found that large amount of energy can be extracted with comparatively larger value of torque. Experiment have been carried out on single rotor wind turbine and then dual rotor wind turbine after turbine development in the real atmospheric condition due to which different torque, power produced, rotor speed was achieved which was analyzed and found fruitful where a large amount of power or torque is required.

Keywords- Single Rotor Wind Turbine (SRWT), Dual Rotor Wind Turbine (DRWT), Tip Speed Ratio (TSR)

I. INTRODUCTION

As we know that conventional energy recourses will abolish one day the only left energy resources is only natural recourses wind energy is one of them. With the use of this wind turbine set up we can use it as a micro power generation unit due to which transmission cost may be reduce because about 50 percent of transmission losses occurs in power transmission with grid which can be easily reduce using this set up moreover natural recourses never having negative effect on nature. Instead of power generation this set up can be used directly to the devices to rotate it simultaneously like compressor and wind operated water pump and where there is comparatively larger value of torque is required. Basically we are having lots of challenges in wind power utilization like low velocity producing lower torque value for wind,

wind rotor imbalance and lots of more, moreover for conventional wind rotor it was very difficult task to balance wind turbine, effort have been made to short out these challenges with dual wind rotor. As we know that normally single horizontal axis wind turbine used widely for power production as in general not so much research have taken place in dual rotor analysis but still some references have been taken into consideration with designing and analysis have also been made for different aspect of TSR (Tip Speed Ratio), wind velocity in order to analyze torque and power. Many research paper have been published for dual rotor wind energy utilization but most of them have been used the counter rotating rotor their research have discussed as follows. [1] Observed that power produced have been increases maximum up to 9.67% by using counter rotor with different diameter with placing a primary rotor at different location (0.3d to 0.65 d). Jung et al [2] has obtain power curve analytically for a 30 KW CRTWT system and also the effect of distance and diameter b/w the dual rotor. [3] Measured The Rotor Performance And Analysis on counter rotating wind turbine. [4] It was theoretically showed that in the case of multiple or dual rotors with the same radius, the power coefficient can be further increased, approximately by 13% compared to the single rotor case. The limitations of this paper have been determined by flow visualization that showed in accurate results from a distance equal to a half of a disc diameter. [5] A theoretical model aimed to improve the power extraction from wind is proposed in which considers two co-axial rotors these rotors are smaller than the front rotor and placed about in the inner blade region of the front rotor. The central part of the upstream rotor (76.2% of the rotor diameter) doesn't extract wind's energy because it has no blades present. After further calculation, it was shown that the theoretical power coefficient depends on the induction velocities. For the analyzed case, the maximum power coefficient of 0.814 was obtained. [6] It was found that the system is more efficient at low rotational speeds (16-60 rpm), the energy extracted from wind can increase up to 40% compared with the single rotor case and the bending stress over the tower is less. [7] Parametric sweeps using simulations show that secondary rotor turbine size should be 25% of the main rotor and it if be axially separated from the main rotor by a distance of 0.2 times the main rotor radius then a net benefit of 7% in C_p . Milind Deotale [8] have observed that the efficiency of overall system is maximum at higher speeds with 60% but goes on decreasing to 28 from 30% at lower wind speeds. But at optimum speeds the average efficiency is 45%.

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II. METHODOLOGY

Set up for experimental analysis

Experimental set up consist of different components of DRWT which are as follows-

- Rotor blade (Design in structural Design Analysis.)
- Hub
- Central rod
- Bearings
- Foundation etc.

Different components have been assembled to have various results in terms of power torque and their comparison.

III .STRUCTURAL DESIGN ANALYSIS

Design of Blade

While designing wind rotor some reference have been taken where as some design calculation rotor is designed. After designing a drawing was carried out with the help of CATIA software then experimented component have been developed to proceed for experiment.

Calculation of Rotor Diameter,

$$P = C_p (0.5) * \rho * A * V^3$$

[8] Where: P is the power output C_p is the expect coefficient of performance (0.4 for a modern three to six bladed wind turbine) ρ is the air density which can be taken as 1.25 kg/m^3 , A wind turbine frontal area. V is the velocity of wind.

For small wind turbine production we have taken maximum 600W power if for max 10 m/s air/wind speed

Calculation for this rotor diameter

$$600 = 0.4 * 1.25 * 0.5 * A * 10^3$$

The expected electrical and mechanical efficiencies 0.9 [8].Electrical conversion is not required because no conversion is taking place. Calculated diameter 174 cm exactly after production it is about 152 cm diameter dual rotor radius.

Design based on Tip speed ratio-

As [10] low tip speed ratio is used for high torque and high tip speed ratio is used for low torque so as our requirement is high torque thus selected low tip speed ratio 1-3 [10], According to the type of application, we can choose a tip speed ratio λ . For an application of water-pumping windmill, for which greater torque is needed, use $1 < \lambda < 3$. The higher speed machines required less material for the blades and have smaller gearboxes, but require more sophisticated airfoils. -Choose the number of blades, B , from Table-1. Note: if fewer than three blades are selected, there are a number of structural dynamic problems that must be considered in the hub design. As per reference for given (λ) lamda number of blades are taken as 6 [10]

From [10] table 1 we have taken ,Table 2 blade 3 – 6

-Select an airfoil. If $\lambda < 3$, curved plates can be used. If $\lambda > 3$, use a more aerodynamic shape. Ref [10]

As per ref [11] curve shaped blade have been taken into consideration with 45 degree angle of attack or blade tiltation for easy development of model and effective power consideration. Hub and central rod have been designed as per convenience.

Material selection

As we know while designing wind turbine weight must be taken as low as possible thus aluminum have taken into consideration. Rest dimension as given in figure. Normal pressure of 1 bar. Analysis is made for two symmetric blade assembly of 6 number of blade on each rotor ,two wind rotor on same shaft have been analyzed and then result are compared With the single rotor.

Blade model dimension on CATIA

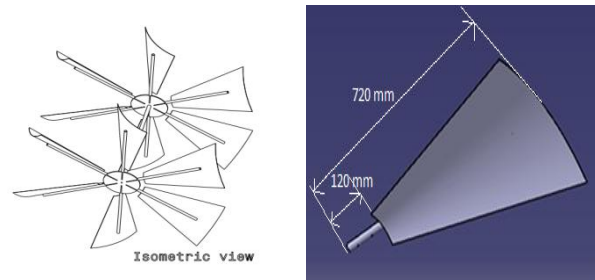
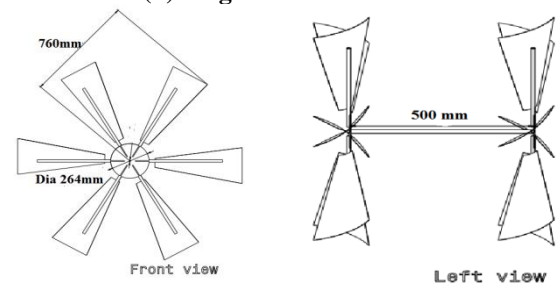


Fig. 1 (a) Isometric view of dual rotar 6 blade assembly
(b) Single blade catia model .



(c)Front view of blade assembly.(d) Side view coaxial shaft dual rotor.



Fig. 2(a) Side view of real dual rotor assembly, (b) Anemometer wind speed and temperature measuring instrument.

Our main objective is to find out or compare different parameter like power output, torque and velocity output of wind rotor in between as follows,

- Single rotor wind turbine.(SRWT)
- Dual rotor wind turbine.(DRWT)

The above different set up is analyzed at different velocity input .Two symmetric rotor with 6 number of blade are used as per given figure ,as our main objective is to find out the best result using dual rotor so the blade profile are used simply without any complicated shape and curve. Blade tiltation is taken 45 degree from vertical.

Wind turbine radius 76 cm .Frontal area of wind turbine 1.813 m²

Here from one side air at different velocity entered the single and then dual rotor due to which dual rotor rotates and with the conversion of wind energy into rotational energy of wind thus enhanced power extraction from wind energy take place which can be further used in various applications.

IV RESULT AND ANALYSIS

Experimented result have been carried out usually in day time of between 1 pm to 4 pm where wind speed is considerably very high , Readings have been noted for about 77 days in real working condition .Readings were noted experimentally for single rotor i.e. SRWT and then for dual rotor i.e. DRWT at the real wind speed , with the available wind speed and wind power single rotor and dual rotor performance were noted ,central rod of 0.025m radius was taken on which torque was carried out, torque and power were calculated in terms of braking load / torque over central shaft then the power produced and coefficient of power Cp are calculated in terms of table as given then the variation was plotted and their comparison was observed. Out of hundreds of readings 16 readings have been considered which are as follows,

(a)Performance comparison between SRWT and DRWT rotor speeds and TSR vs wind speed, table and graph plotted.

Table 1

S No	Wind speed (m/s)	Single Rotor Speed (rpm)	Single Rotor TSR	Dual Rotor Speed (rpm)	Dual Rotor TSR
1	2.40	35	1.16	18	0.60
2	2.80	40	1.14	28	0.80
3	3.00	52	1.38	38	1.01
4	3.20	58	1.44	44	1.09
5	3.80	94	1.97	84	1.76
6	4.00	98	1.95	94	1.87
7	4.50	117	2.07	112	1.98
8	4.80	127	2.10	124	2.05
9	5.20	138	2.11	136	2.08
10	5.60	152	2.16	153	2.17
11	5.80	154	2.11	160	2.19
12	6.00	160	2.12	164	2.17
13	6.40	168	2.09	172	2.14
14	6.80	178	2.08	198	2.32
15	7.00	186	2.11	212	2.41
16	7.40	194	2.09	234	2.52

Experimented data which shows the variation of wind speed, rotor speed and TSR in dual and single rotor wind turbine.

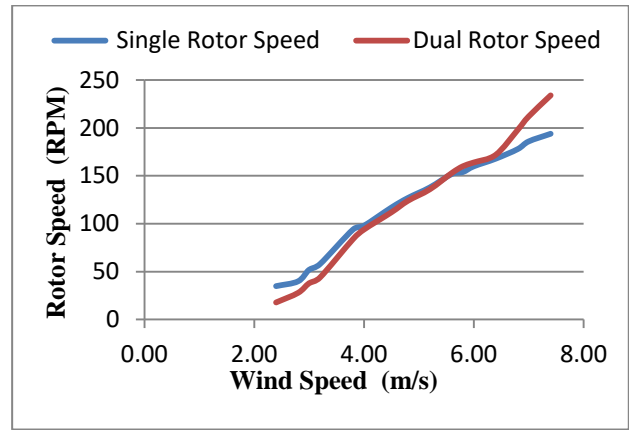


Fig 3.1 Graph represented on wind speed vs rotor speed rpm between the comparison of single and dual rotor.

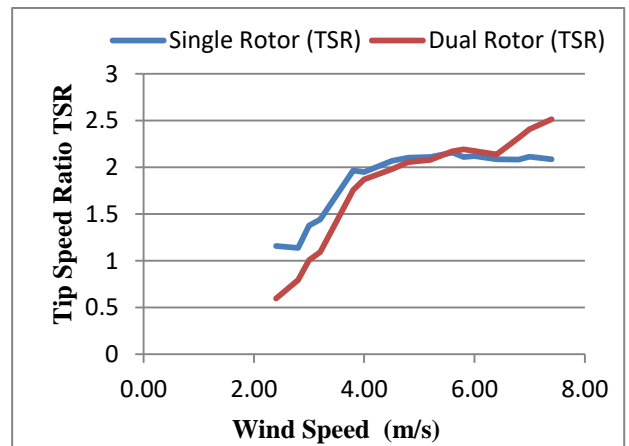


Fig 3.2 Graph represented on wind speed vs TSR (Tip Speed Ratio) between the comparison of single and dual rotor.

-Comparison between SRWT and DWRT in term of rotor speed vs wind speed -From large number of experimental reading graph between wind speed and rotor speed have been plotted which is represented on Fig 3.1 as per experimental graph at the initial state of wind speed of 2.4m/s SRWT rotor rpm is about 94.44 % more than DRWT. In the range of 2.4 m/s to about 5 m/s rotor speed single ,rotor speed is comparatively high as compare to dual rotor thus but as the wind speed increases beyond 5 m/s to 7.4 m/s it has been observed that rotor speed of dual rotor wind turbine increases after definite value 5m/s , maximum rotor rpm of SRWT of value 194 rpm at 7.4 m/s where as dual rotor DRWT achieved 234 rpm at the same max wind speed of 7.4 m/s means maximum rotor speed of DRWT is 20.61 % more than SRWT at 7.4 m/s of wind speed .

Comparison between SRWT and DWRT in term of TSR vs wind speed data obtain from experimental analysis is obtain on graph 3.2 which shows that for SRWT min TSR is 1.16 at 2.4 min wind speed and maximum TSR is 2.16 at 5.6m/s where as for DRWT min TSR is .5966 at 2.4 m/s of min wind speed and maximum TSR is 2.51 at max wind speed of 7.4 m/s, means at initial state SRWT ,TSR is 94.44 % more than DRWT, but for DRWT as the speed increases beyond certain limit the value of TSR for DRWT increases more rapidly than SRWT,

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the maximum value of TSR for DRWT is about 16.1 % more than the TSR of SRWT .It also have been observed that maximum TSR of SRWT is 2.16 at 5.6 m/s but the maximum value of TSR for DRWT is 2.51 at 7.4 m/s..

(b)Performance comparison between SRWT and DRWT, braking load and torque vs. wind speed, table and graph plotted.

Table 2

S No	Wind speed (m/s)	Single Rotor Braking load (N)	Single Rotor Braking Torque (Nm)	Dual Rotor Braking load (N)	Dual Rotor Braking Torque (Nm)
1	2.40	23.54	0.59	39.24	0.98
2	2.80	37.28	0.93	47.09	1.18
3	3.00	39.24	0.98	60.82	1.52
4	3.20	43.16	1.08	66.71	1.67
5	3.80	51.01	1.28	77.50	1.94
6	4.00	58.86	1.47	87.31	2.18
7	4.50	70.63	1.77	95.16	2.38
8	4.80	82.40	2.06	116.74	2.92
9	5.20	102.02	2.55	137.34	3.43
10	5.60	117.72	2.94	150.09	3.75
11	5.80	121.64	3.04	174.62	4.37
12	6.00	125.57	3.14	188.35	4.71
13	6.40	131.45	3.29	196.20	4.91
14	6.80	137.34	3.43	221.71	5.54
15	7.00	145.19	3.63	225.63	5.64
16	7.40	155.00	3.87	238.38	5.96

Experimented data which shows the variation of braking load and braking torque in dual and single rotor wind turbine.

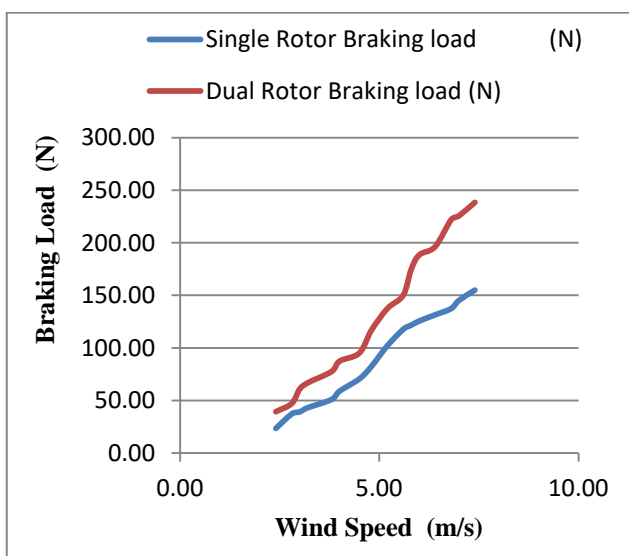


Fig 3.3 Graph represented on wind speed vs braking load (N) between the comparison of single and dual rotor of central rod.

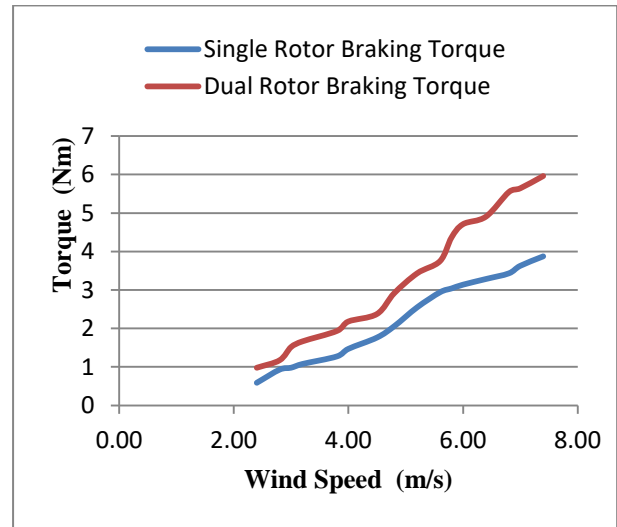


Fig 3.4 Graph represented on wind speed vs Torque between the comparison of SRWT and DRWT.

Comparison between SRWT and DWRT in term of braking load and torque vs wind speed -As we have directly calculated braking load which as applied at the effective radius of 25 mm as the wind speed increases torque generated on the central shaft of single and dual rotor wind turbine, a counter load is applied to find out braking load in kg which is calculated and it value can be calculated in Newton thus obtaining braking torque ,the effect of braking load and braking torque is similar by percentage in comparison for SRWT and DRWT. Experimental reading have been carried out of a single rotor and dual rotor wind turbine, in order to find out power developed but single rotor wind turbine and dual rotor wind turbine first braking torque have been calculated with help of load measurement device digital and anemometer for respected wind speed, for the calculation of braking torque baking load was applied on central rod of effective radius of 25 mm. From graph 3.3 it has been observed that at initial an final both the places braking torque for dual rotor is having more braking torque than single one, at the initial stage of 2.4 m/s of wind speed dual rotor wind turbine torque 0.98Nm which is 66.10%percent more than single rotor wind turbine assembly where as at the maximum wind speed of 7.4m/s dual rotor generates 53.99% percent more torque as compare to single rotor wind turbine. In this way we can easily see that in order to achieve more torque this dual rotor wind turbine will be the better option than a single rotor wind turbine.

c) Performance comparison between SRWT and DRWT power developed, wind power vs wind speed , table and graph plotted.

Table 3

S No	Wind speed (m/s)	Wind power (W)	Single Rotor Shaft Power (Watt)	Single Rotor (Cp %)	Dual Rotor Shaft Power (Watt)	Dual Rotor (Cp %)
1	2.40	15.67	2.16	0.138	1.85	0.118
2	2.80	24.88	3.90	0.157	3.45	0.139
3	3.00	30.61	5.34	0.174	6.05	0.198
4	3.20	37.14	6.55	0.176	7.68	0.207
5	3.80	62.20	12.55	0.202	17.03	0.274
6	4.00	72.55	15.09	0.208	21.48	0.296
7	4.50	103.29	21.62	0.209	27.89	0.270
8	4.80	125.36	27.38	0.218	37.88	0.302
9	5.20	159.38	36.84	0.231	48.87	0.307
10	5.60	199.07	46.82	0.235	60.09	0.302
11	5.80	221.17	49.02	0.222	73.11	0.331
12	6.00	244.84	52.57	0.215	80.83	0.330
13	6.40	297.15	57.79	0.194	88.30	0.297
14	6.80	356.42	63.97	0.179	114.87	0.322
15	7.00	388.80	70.66	0.182	125.16	0.322
16	7.40	459.34	78.68	0.171	145.96	0.318

Experimented data which shows the variation of power coefficient in dual and single rotor wind turbine.

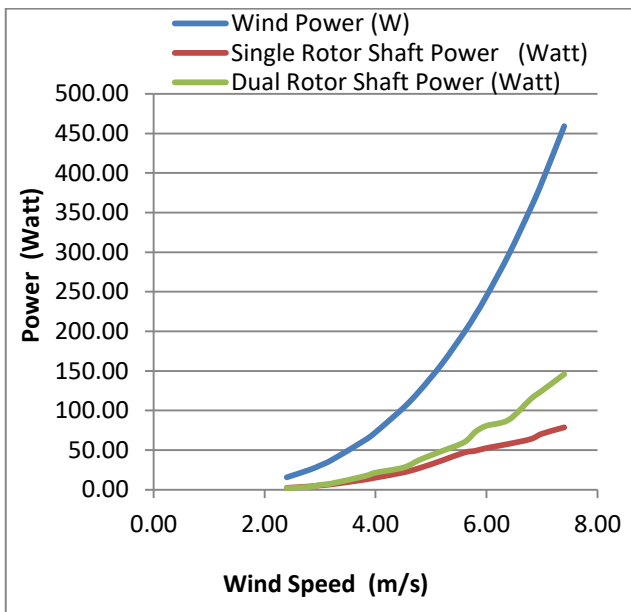


Fig. 3.5 Graph plotted between Wind power Single rotor shaft power and dual rotor shaft power vs wind speed.

-Comparison between SRWT and DWRT in the form of their power produced which is compared with the available wind power on the common wind speed. From the experimental result it has been observed that wind speed is minimum of 2.4 m/s and the maximum of 7.4 m/s in this range power calculation reading have been calculated from given equation a. It has been observed from the graph that at initial stage of wind speed single rotor is generation more power which was 16.65 percent more as compared to dual rotor wind turbine at 2.4m/s but power generation by

dual rotor wind turbine increases beyond certain limit which increases with the increases in wind speed at maximum wind speed of 7.4 m/s dual rotor power was 85.55 % more than single rotor.

iv) Performance comparison between SRWT and DRWT power coefficient developed vs wind speed.

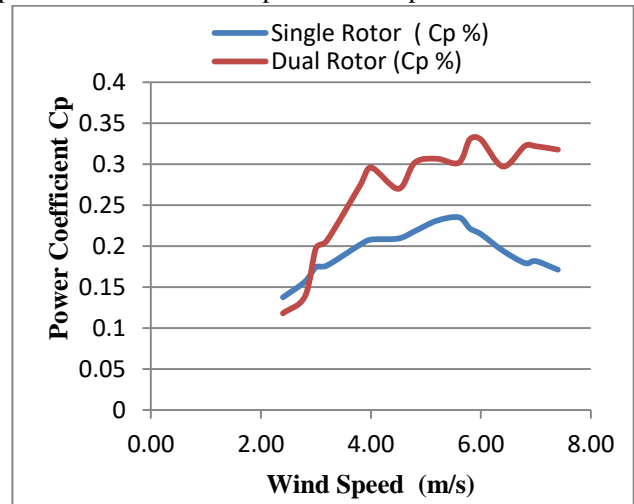


Fig. 3.6 Comparison of coefficient of power produced by single rotor wind turbine and dual rotor wind turbine for the respective wind power. Comparison between SRWT and DWRT in term of coefficient of power Cp vs wind speed - In the same way we observed the low value of power coefficient at the beginning of wind speed for dual rotor as compare to single one whereas s power coefficient value for dual rotor increases after certain value of wind speed at 2.4 m/s of wind velocity single rotor is having 16.1% percent more power coefficient value as compare to DRWT whereas at maximum speed of 7.4 m/s , dual rotor is having 40.63 percent more value than single rotor. For SRWT the maximum value of cp for SRWT is 23.50% at 5.6m/s of wind speed, where as the minimum value of cp is 13% at 2.4m/s, for DRWT max value of cp is 33.05% at 5.8 m/s of wind speed which is 40.63% more than SRWT and minimum value of cp is 11.8 %.

V RESULT AND DISCUSSION

As per the above experimental readings it has been observed that in terms of rotor speed and TSR initially SRWT rotor speed is higher than DRWT but as the speed increases beyond certain limit DRWT will produce more rotor speed which is about 20.61 % more than SRWT. In term of braking load and torque initially and finally wind speed DRWT produces more torque which is about 54 % more than SRWT that means DRWT is useful where large amount of torque is required as compared to SRWT. As far as the power is concern DRWT produces more power compared to SRWT at the same wind speed. At initial power produce by the SRWT is higher but after certain wind speed power increases much rapidly in DRWT as compared to SRWT, where as the power coefficient for SRWT at initial is higher than DRWT by 10.16 percent% but at max wind speed of 7.4 m/s for DRWT power coefficient is 0.3305

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(collaborative SRWT an DRWT) which is about 40 % more than SRWT max power coefficient in this way we can say that dual rotor wind turbine is having better performance at certain high speed as compared to SRWT.

VI CONCLUSION

When we talk about power coefficient from dual rotor wind turbine as compare to single rotor experimentally then we observed that, dual rotor is having its value about 40 % more than single rotor wind turbine that means dual rotor wind turbine will perform better way in term of power produced .In the same way torque and rotor wind speed is also better in dual rotor wind turbine as compared to single one ,after certain wind speed. Thus dual rotor wind turbine can be used where large amount of torque, rotor speed and power is required with the better degree of stability. Because the weight of turbine is distributed symmetrically on both side of center of gravity of turbine .Finally it is concluded after observation of our experimental results, that after certain wind speed dual rotor wind turbine will perform better as compare to single rotor wind turbine in terms of Power produced, Rotor speed and Torque. We can further proceed our research on this dual rotor wind turbine after any specific modification and addition to improve its performance which can be useful in the field of power production from wind turbine.

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Vinay Mishra working as an Asst professor in Ambalika Institute of Management & Technology ,Lucknow Uttar Pradesh India, is having more than 10 years of teaching experiences along with defence industrial experience , he published many papers in national and international journals , he had completed his engineering in mechanical branch from UPTU in 2006,he is an active lifetime member of ISTE i.e. Indian Society for Technical education. He worked on many defence Govt projects like Su 30, LCA (Light Combat Aircraft) etc. He had gone thru various training program under Govt of India, ministry of defence. He is well known for his teaching ability in relevant areas. He is pursuing his Ph.D. from AKTU Lucknow, his main research field are thermal engineering, turbo machinery and renewable energy resources.



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