# Improving Efficiency of Counter Rotating Wind Turbine

Dr.Naresh kumar
Asst Professor DCRUST, Murthal
drnareshrajk@gmail.com
Amresh kumar
M-tech student
Department of Electrical Engineering
DCRUST University, Murthal, India

*Abstract :* This paper presents a study and performance of a dual rotor wind turbine with counter rotating rotor blade connected back to back on a tower to a particular electric generating unit, (permanent magnet DC generator in this case (PMDG) and the efficiency of this system is compared with the traditional single rotor wind turbine(SRWT )[1] at varying wind speed is done and to increase the relative speed between magnetic field and armature conductor ,field as well as armature is being rotated opposite of each other.

***Index Terms* - Component,formatting,style,styling,insert.**

## I. Introduction

For meeting growing demand of electricity for industry and for households it is becoming quite difficult for conventional sources of energy to balance the demand with generation at the same time maintaining environmental pollution. So need to use renewable sources of energy such as wind energy in coordination with the conventional sources, it will generate pollution free energy at the same time maintain balance between generation and demand .wind energy converts wind power in mechanical rotational power in turbine blade which is connected to a suitable electric generating unit which convert mechanical power in electrical energy. However various factors can affect the amount of wind energy generated in all of them velocity of wind, duration and type of wind play important role.

## II. LITRATURE REVIW

When a single rotor wind turbine is used for energy conversion, only a part of the available energy in the wind is extracted. The maximum power that can be extracted from the wind is about 59% of the available energy also called Betz limit of single rotor wind turbine according to Betz theory velocity change across the turbine, is 2/3 of primary velocity of wind[1] .so in practice, the energy behind a single rotor is not very small. Part of this energy can be extracted further by installing a second rotor in coordination with the primary rotor [2]. Now according to Bets velocity change (2/3) across second turbine takes place, primary turbine is connected with the armature through a suitable gear box and secondary is connected with the field through gear box of same alternator both rotor blade having opposite pitch angle so that they are rotating in opposite direction of each other and hence we get increased relative velocity according to faraday law of electromagnetic induction enable this design to generate enough voltage in low wind speed area[3].

- **Performance coefficient ($c_p$)**

Performance coefficient or energy conversion constant ($c_p$) is defined as the maximum amount of wind energy that is being Converted by any wind turbine into rotational energy of turbine blade is basically considered as performance coefficient of wind turbine, it's value changes turbine to turbine and depends upon various factors some of which are tip speed ratio (TSR) of wind turbine and the pitch angle of different turbine blades

- **Tip speed ratio(TSR)**

The tip speed ratio for wind turbines is the ratio between the rotational speed of the tip or tangential speed of a blade and the actual velocity of the wind .It's basically non dimensional in nature

### III. PROPOSED FORMULA FOR CALCULATING POWER IN CRWT

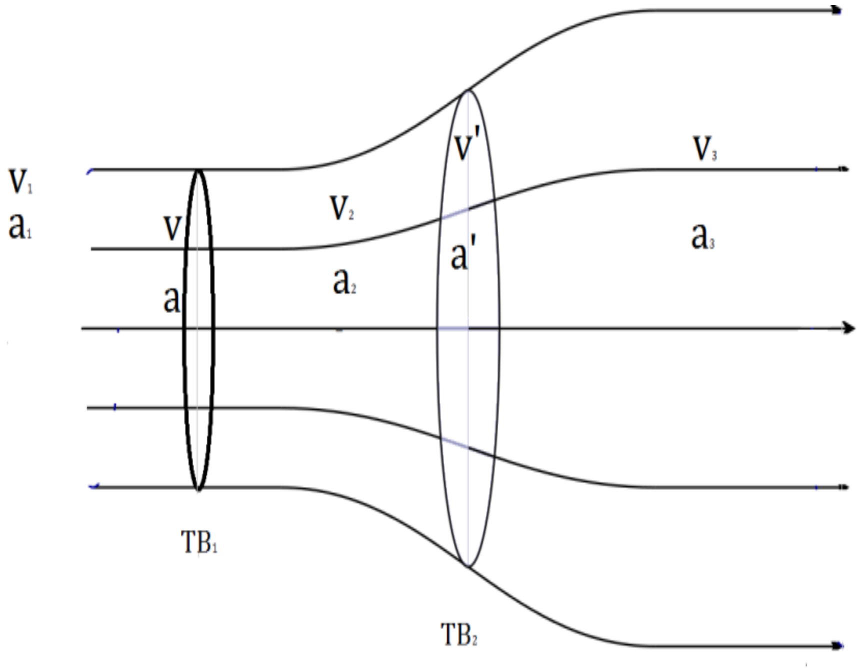


Fig.1 Cross-sectional view of CRWT and corresponding measures

Mass (m) =area $(a)$*density $(\rho)$*velocity $(v)$*time (t)

Differentiating above equation with respect to time

$$\frac{dm}{dT} = \dot{m} = a\rho v \cdots\cdots\cdots (1)$$

Applying continuity equation

$$\dot{m} = \rho a_1 v_1 = \rho a' v' = \rho a v = \rho a_2 v_2 = \rho a_3 v_3 = \text{constant} \cdots\cdots\cdots (2)$$

Force acting on turbine blade

$$F = \dot{m}a = \dot{m}\frac{dv}{dt} \cdots\cdots\cdots (3)$$

$$F = \dot{m}\Delta v \cdots\cdots\cdots (4)$$

$$F = a\rho v\Delta v \cdots\cdots\cdots (5)$$

For turbine one

$$f_1 = a\rho v\Delta v = a\rho v(v_1 - v_2) \cdots\cdots\cdots (6)$$

Similarly for turbine two

$$f_2 = a'\rho v'\Delta v' = a'\rho v'(v_2 - v_3) \cdots\cdots\cdots (7)$$

Incremental work done by the wind stream is

$$\partial w = f\partial X$$

$$\text{Power} = \frac{dw}{dt} = f\frac{dx}{dt}$$

$$\therefore power(p_1) = f_1 v$$

$$\therefore power(p_2) = f_2 v'$$

For elemental change

$$p = \frac{\Delta w}{\Delta t}$$

For turbine 1(TB$_1$)

$$p_1 = \frac{\frac{1}{2}(mv_1^2 - mv_2^2)}{\Delta t} = \frac{1}{2}\dot{m}(v_1^2 - v_2^2) \cdots\cdots\cdots (8)$$

$$p_1 = \frac{1}{2}\{a\rho v(v_1^2 - v_2^2)\} = a\rho v^2(v_1 - v_2) \cdots\cdots\cdots (9)$$

{Here $v = \frac{1}{2}(v_1 + v_2)$ *is mean velocity*}

Similarly four turbine second ($TB_2$)

$$P_2 = \frac{1}{2}\{a\rho v'(v_2^2 - v_3^2)\} = a\rho v'^2(v_2 - v_3)$$

{Here $v' = \frac{1}{2}(v_1 + v_2)$*is mean velocity*}

Defining a velocity factor ( $k$)

$$k = \frac{downstream\ velocity}{upstream\ velocity} \cdots\cdots\cdots (10)$$

For turbine one ($TB_1$)

$$k_1 = \frac{v_2}{v_1}$$

For turbine second ($TB_2$)

$$k_2 = \frac{v_3}{v_2}$$

Using previous equations

$$p_1 = \frac{1}{4}a\rho v_1^3\{(1 - k_1^2)(1 + k_1)\} \cdots\cdots\cdots (11)$$

$$p_2 = \frac{1}{4}a'\rho v_2^3\{(1 - k_2^2)(1 + k_2)\} \cdots\cdots\cdots (12)$$

Total power extracted is sum of two turbine powers that is

$$p_{net} = \frac{1}{4}\rho[av_1^3(1 - k_1^2)(1 + k_1) + a'v_2^3(1 - k_2^2)(1 + k_2)] \cdots\cdots\cdots (13)$$

Let the performance coefficient of individual turbines be $c_{p_1}$ *and* $c_{p_2}$ *respectively*

$$c_{p_1} = \frac{1}{2}(1 - k_1^2)(1 + k_1)$$

$$c_{p_2} = \frac{1}{2}(1 - k_2^2)(1 + k_2)$$

On applying maxima-minima to find maximum performance coefficient

$$\frac{dc_{p_1}}{dk_1} = \frac{1}{2}\{1 - 3k_1^2 - 2k_1\}$$

$$\frac{dc_{p_2}}{dk_2} = \frac{1}{2}\{1 - 3k_2^2 - 2k_2\}$$

On equating differential term equals to zero

$$k_1 = \frac{1}{3} or - 1 = \frac{v_2}{v_1}$$

$$k_2 = \frac{1}{3} or - 1 = \frac{v_3}{v_2}$$

In this case $k_1 = -1$ *and* $k_2 = -1$ *is unwanted*

$$\therefore for\ maximum\ perfomance\ coefficent\ down\ stream\ velocity = \frac{1}{3} of\ upstream\ velocity$$

$$\therefore c_{p_1} = c_{p_2} = c_{p_{max}} = \frac{16}{27}\ is\ called\ bez's\ limit$$

For turbine one ($TB_1$)

$$p_1 = [\frac{16}{27}\left\{\frac{1}{2}\rho a v_1^3\right\}] \cdots\cdots\cdots (14)$$

$$p_2 = \left[\frac{16}{27}\left\{\frac{1}{2}\rho a' v_2^3\right\}\right] \cdots\cdots\cdots (15)$$

Net power extracted by simultaneous operation of to turbines is

$$p_{net} = [\frac{16}{27}\rho\left\{\frac{1}{2}\left(av_1^3 + a'^{v_2^3}\right)\right\}] \cdots\cdots\cdots (16)$$

*considering radious of first and second turbine be r and r′ respectively*

$$\therefore a = \pi r^2\ and\ a' = \pi r'^2$$

$$\therefore p_{net} = [\frac{16}{27}\pi\rho\left\{\frac{1}{2}\left(r^2 v_1^3 + r'^2 v_2^3\right)\right\}] \cdots\cdots\cdots (17)$$

From above equation increase in power extracted is given by

$$\Delta p_{insrese} = \frac{16}{27}\left[\left\{\frac{1}{2}\left(\pi\rho r'^2 v_2^3\right)\right\}\right] \cdots\cdots\cdots (18)$$

For maximum power change $v_2 = \frac{1}{3}v_1($

$$\therefore \Delta p_{insrese} = \frac{16}{27}\left[\left\{\frac{1}{54}\left(\pi\rho r'^2 v_1^3\right)\right\}\right] \cdots\cdots\cdots (19)$$

## IV. RESULTS AND DISCUSSION

A. Case one taking radios of both turbine blades equal that is $r = r'$ and varying wind speed for both SRWT and CRWT

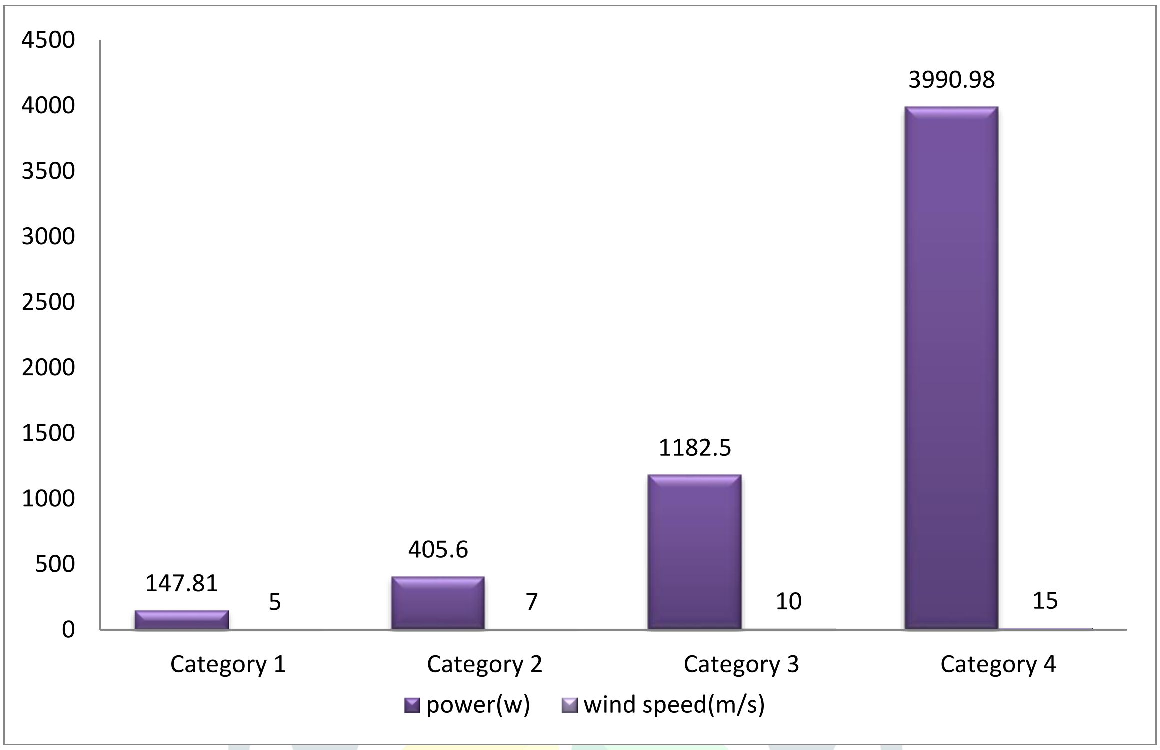


Fig.2 Power content in CRWT at different wind velocity

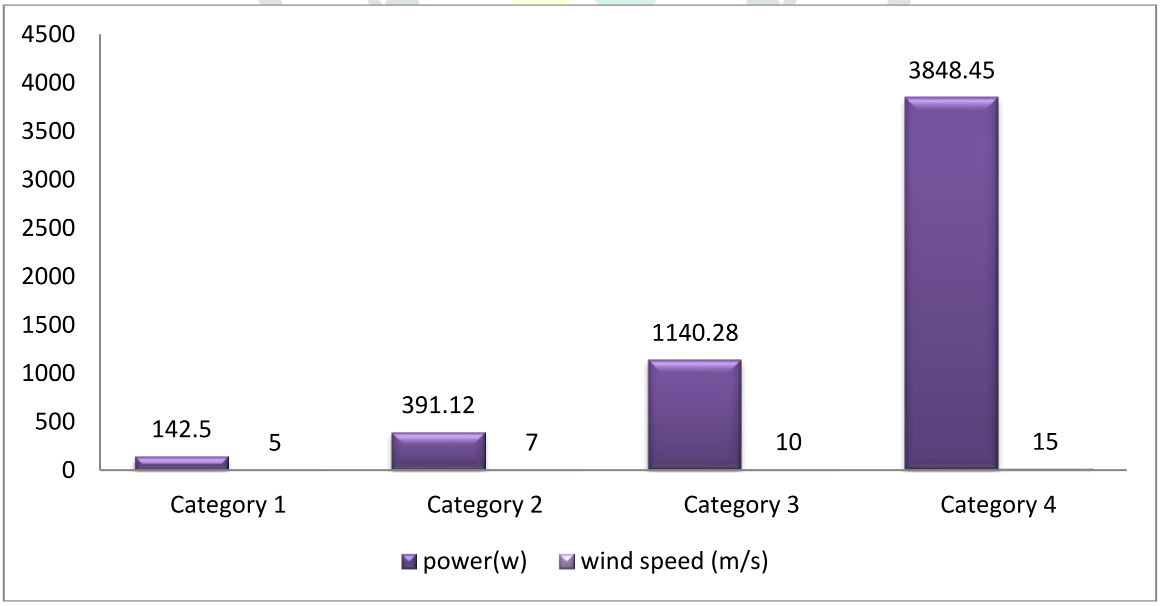


Fig.3 Power content in SRWT at different wind speed

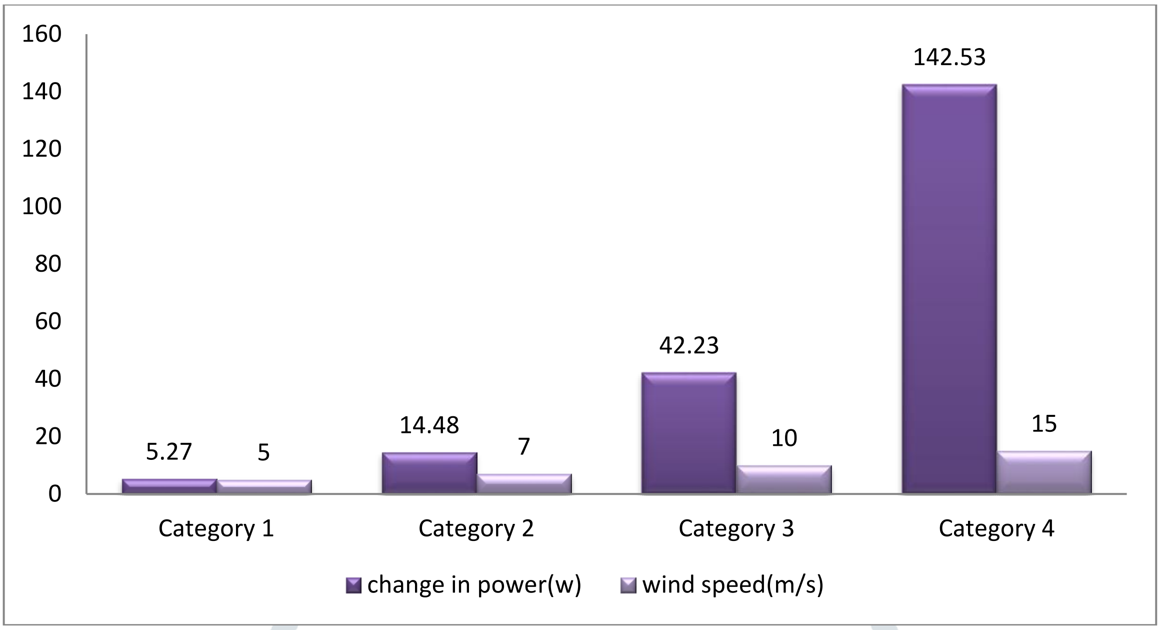


Fig.4 Maximum difference of power content in CRWT and SRWT

B. In this case radius of turbine one as 1meter and that of turbine blade second which is behind turbine first as 1.5 meter and varying wind speed for both CRWT and SRWT.

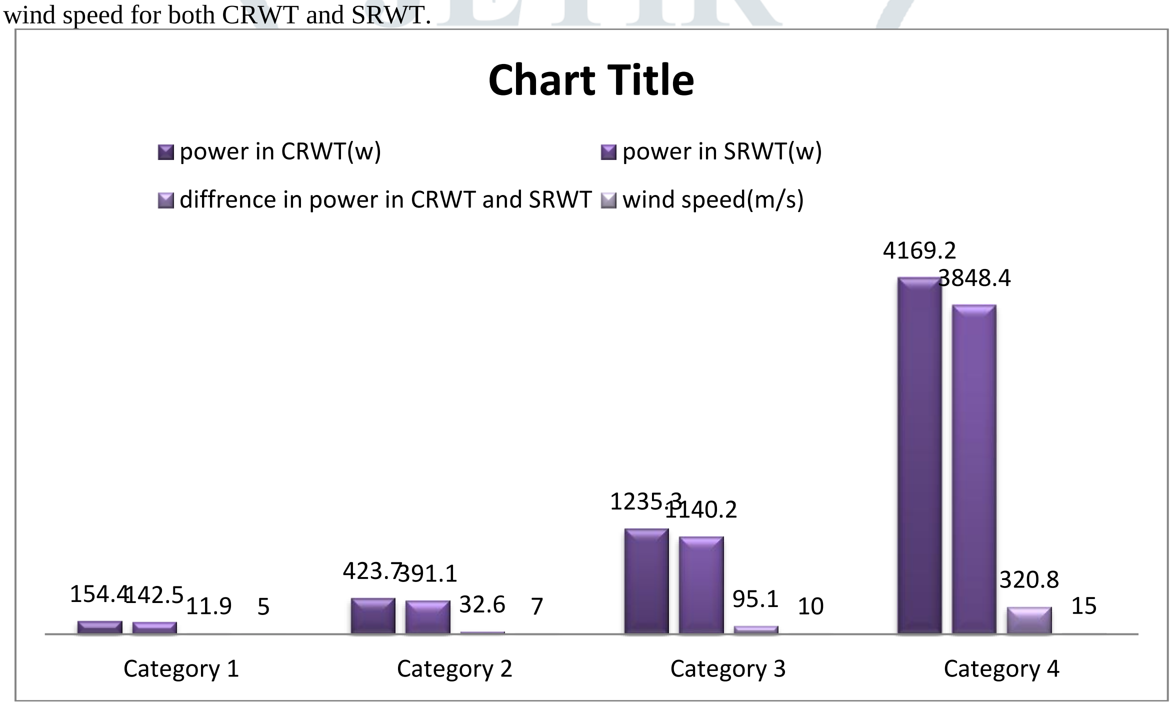


Fig.5 Power content in CRWT, SRWT and there difference of power at varying wind speed

In the above calculation it has been shown that the extracted power content in counter rotating wind turbine (CRWT) is greater than that of conventional single rotor wind turbine (SRWT) and also the difference in extracted power is more if both the rotors has different radius .and also such an arrangement will allow to harness wind power even at low wind velocity because of their counter rotating nature, and suitable for meeting growing demand of electrical power .

## REFERENCES

[1] Betz A. Das Maximum der theoretisch möglichen Ausnutzung des Windes durch Windmotoren. Gesamte Turbinenwesen 1920;17:307e9.
[2] Hau Erich. Wind turbines: fundamentals, technologies, application, economics. New York: Springer; 2000. pp.67e80.
[3] Newman B. Multiple actuator-disc theory for wind turbines. J Wind Eng Ind Aerodyn 1986;24(3):215–25.