Efficiency Improvement of Counter Rotating Wind Turbine and Overall Installation Cost Reduction

By Special Arrangement of Its Secondary Turbine

Amresh kumar, Dr. Naresh kumar
M.tech scholar, Asst Professor
Electrical Engineering Department
DCRUST, Murthal, India

Abstract: This paper presents a special modification in the arrangement of the secondary turbine of counter-rotating, dual rotor wind turbine for increasing efficiency and reducing overall installation cost. In this arrangement instant of placing secondary turbine just behind the primary turbine, it has been placed side-by-side with opposite pitch angle of each other so that both primary and secondary turbine simultaneously face incoming wind directly and rotate opposite to each other, such arrangement can improve the efficiency of CRWT twice of the conventional single rotor wind turbine.

Index Terms - CRWT, SRWT, DUAL ROTOR

I. INTRODUCTION

As of growing demand of electricity for the industrial and commercial expansion of developing country like India and considering the global warming it’s been obvious and natural choice to balance increasing demand with the generated power from renewable energy such as solar and wind. But due to low efficiency of wind and solar and unavailability of solar power at night and huge cost of using battery at night, wind energy will be best choice for compensating growing demand of electricity. Several new techniques have been introduced. In this paper an efficient method has been introduced for the generation of wind energy by using counter rotating wind turbine (CRWT) economically and efficiently, the overall installation cost of wind turbine can also be reduced to large instant.

II. LITERATURE REVIEW

In a conventional three blade single rotor wind turbine the maximum wind energy that can be converted into rotational energy of the turbine shaft is limited to 59.25 percent of the total energy of the wind, this term is well known as Betz coefficient or the coefficient of power or the turbine conversion efficiency however it can’t represent overall efficiency of wind turbine because it consists of various losses such as losses in the bearing windage friction, friction due to gearbox etc, so the modern most efficient wind turbine can only extract 35-40 percent of Betz coefficient no single rotor wind turbine can extract wind power more than that of Betz coefficient. However in case of counter-rotating wind turbine (CRWT) by using two back to back turbines with rotation opposite to each other it is possible to extract more energy through the secondary turbine, since the downstream wind velocity of the primary turbine remains only 33.33 percent of its upstream velocity, the extracted power by secondary turbine is approximately 24.10 percent which may be increased by changing the position of the secondary turbine blade.

III. PROPOSED MODEL OF CRWT

In this proposed model of CRWT, the two turbines of CRWT are placed side-by-side with each other instead of placing back to back and generating unit is connected through the gear and a connecting shaft. The two turbines are placed such that there is no interference of the rotation of one turbine on the other (neglecting small interferences due to Tip of the turbine). The two turbines are arranged in such a manner that, the direct impact of moving air on both the turbine simultaneously. Since in this case the secondary turbine of CRWT faces incoming wind directly so it can also extract power up to Betz limit (59.25 percent) whereas in case of the back-to-back arrangement of turbines it will be only 24.10 percent. Due to the increase in power generation the per unit cost of generation reduced from the conventional CRWT. In the proposed model of CRWT size of primary as well as the secondary turbine is the same, which again enhance the mechanical stability of CRWT and the cost of the large secondary turbine. The overall
maximum power extracted by side-by-side placed counter turbines can be increased to the double of single rotor wind turbine, whereas in case of back-to-back turbines in CRWT it is possible to increase up to 24.10 percent.

![Fig.1 side-by-side arrangement of turbines in CRWT](image)

**IV. MATHEMATICAL FORMULATION FOR CALCULATING POWER**

Power content in single rotor wind turbine of cross-sectional area \(A\), and the radius of the turbine \(R\), upstream velocity of wind for the primary turbine is \(V_1\) m/s is given by a mathematical formula

\[
P = \frac{1}{2} \rho AV_1^3
\]

In terms of Betz limit power extracted by a single rotor wind turbine is given by

\[
P = \frac{16}{27} \left(\frac{1}{2} \rho AV_1^3\right)
\]

... ... \(1\)
Equation 1 represents power extracted by a single rotor wind turbine (SRWT) in ideal wind condition.

Now in case of the counter-rotating wind turbine (CRWT) with a back-to-back turbine having radius \( R \) and \( R' \) having upstream wind velocity of primary and secondary turbine are \( V_1 \) and \( V_2 \) respectively. The overall power extracted is given by

\[
P_{\text{total}} = \left[ \frac{16}{27} \rho \left( \frac{1}{2} (AV_1^3 + AV_2^3) \right) \right]
\]

Since the downstream velocity \( V_2 \) is one third of the upstream velocity so extracted power is given by

\[
P_{\text{total in back-to-back}} = \left[ \frac{16}{27} \rho \left( \frac{1}{2} (AV_1^3 + A' \frac{1}{27} V_1^3) \right) \right] \ldots \ldots (2)
\]

In case of back-to-back connection of primary and secondary turbine the upstream velocity of the secondary turbine is the same as that of the downstream velocity of the primary turbine and so the generated power is not as much improved.

However in the case of the counter-rotating wind turbine (CRWT) with the side-by-side arrangement of primary and secondary turbine the upstream velocity of both the turbine is same so the extracted power is given by

\[
P_{\text{total in side-by-side}} = \left[ \frac{16}{27} \rho \left( \frac{1}{2} (AV_1^3 + AV_2^3) \right) \right] = \frac{16}{27} \rho AV_1^3 \ldots \ldots (3)
\]

Equation (3) represents overall power extracted in the case of CRWT when its rotors are arranged side-by-side

The difference in extracted power is given by

\[
P_{\text{total in side-by-side}} - P_{\text{total in back-to-back}} = \Delta P = \frac{16}{27} [\rho \left( \frac{AV_1^3}{2} - A' \frac{1}{27} V_1^3 \right)]
\]

\[
\Rightarrow \Delta P = \frac{16}{27} [\rho \left( \frac{AV_1^3}{2} - A' \frac{1}{27} V_1^3 \right)] \ldots \ldots \ldots (4)
\]

\( \Delta P \) is the amount of additional power extracted from wind due to side-by-side arrangement of its primary and secondary turbine

V. RESULT AND CONCLUSION

a. Power content of counter-rotating wind turbine (CRWT) in which secondary turbine is placed just behind the primary turbine or in back-to-back arrangement \( (R = R' = 1 \text{ metre}) \) and taking \( \rho = 1.225 \)

![Fig.3 Power content in CRWT with back-to-back arrangement](image-url)
b. Power content in the case when turbines are placed side-by-side in CRWT \((R = R' = 1 \, \text{metre} \text{ and taking } \rho = 1.225)\)

\[
\Delta P = \frac{16}{27} \rho \left( \frac{A V_1^3}{2} - A' \frac{1}{27} V_1^3 \right) \quad \text{for this case } R = R' = 1 \, \text{metre} \text{ so that } A = A'
\]
\[
\Rightarrow \Delta P = \frac{16}{27} \rho \left( \frac{A V_1^3}{2} - \frac{A}{27} V_1^3 \right)
\]

VI. CONCLUSION

From the above calculation, it can be seen that the power content in the side-by-side arrangement of CRWT is generating more power for the same physical parameter of turbine and cost with respect to the back-to-back arrangement of turbines in CRWT. The side-by-side arrangement of CRWT has turbine blades of the same size so it will improve the mechanical stability of the overall system, whereas in case of back-to-back-arrangement of turbines in CRWT the secondary turbine has a larger size for extracting maximum power which causes reduction in the stability.
REFERENCES