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DESIGN AND TECHNO- ECONOMIC EVALUATION OF SMALL WIND TURBINE USAGE IN INDIAN POWER SYSTEMS

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Research Article

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ABSTRACT

This article talks about how well wind turbines work in small businesses and homes in rural and urban India. A 3 kW horizontal wind generator with a 4m circle is the prototype that is being looked at. The test was done in a part of south India where there are a lot of wind mills that can be used to make electricity. Real wind conditions were used to test the prototype. For protection against damage from strong winds, the machine has a rotating main shaft that doesn't have a gear box. India needs a lot of power and wants to cut down on smog. As a result, wind turbines for homes and small businesses can be used instead. We did a Techno-Economic Analysis on this project to look at the Return on Investment (ROI) and the problems that come with putting it into action.

Key Words: Return on Investment, Urban, Rural, Industrial Usage, Economic Analysis.

INTRODUCTION

Tamilnadu, a state in the southern part of India, has a lot of possible wind resources. The study was done in the Coimbatore district, which gets its air from the Palghat Pass. When the strong south-west summer monsoon starts in May or June and cool, damp air moves toward the land, it affects the wind in India. The weaker north-east winter monsoon starts in October and cool, dry air moves toward the ocean.

Nomenclature:

C_p – Power Coefficient,	Cl – Coefficient of Lift ,	Cd- Coefficient of Drag,
λ - Tip Speed Ratio,	γ – Yaw Angle ,	a – Axial Induction Factor
B – Blades,	N – Rated speed in rpm,	f – frequency,
L – Lift,	Po – Poles,	D- Drag,
P—Power in the wind,	U- Velocity of wind,	*V*—Voltage,
I- Current,	ROI –Return on Investment,	Hrs/Day- Hours per Day,
Watts/Hr – Watts per Hour		

The winds are always strong on the Indian peninsula in March, except along the eastern coast of the peninsula. In the months of November through March, the winds aren't very strong, but on the Tamilnadu coast, there are times when the winds are stronger.

A wind turbine is a machine that uses the wind to get mechanical energy that is then turned into electricity by a generator. To make the most of the state's wind power potential, small wind turbines with a rated power of less than 5kW need to be built. Small windmills like these can be used by homes and small businesses so they don't have to rely on the government for power.

WIND TURBINE GENERATOR SYSTEM

The prototype is a Horizontal Axis Wind Turbine (HAWT) with a diameter of 4 m and a power level of 3 kW. Table 2 shows the details.The nacelle is made up of Blades that are connected to the Hub,

and the Hub is linked to the main shaft. After that, the shaft is hooked up to the generator (Permanent Magnet).

Table: 1 Specifications of the Wind Turbine Blade

Rotor Diameter	4 m
Blade Quantity	3
Direction	Upwind
Blade Material	Glass Fibre Reinforced Plastic
Rated Output	3000 W
Maximum Output	4000 W
Initial Voltage	48V
Cut-in Wind Speed	3 m/s
Nominal Wind Speed	9 m/s
Storm Stand	upto 45 m/s
Wind Protection	Auto Furl
Rotor Speed	500 Turns Per Minute
Generator Type	PMG(Nd Fe B Grade 50 Magnet)
Working Temperature	-40 to 70^0 C
Annual Avg Energy Production	10,500 kWh
Accumulator(Battery) Type	12V 150 Ah 10 PC
Accumulator Full Charge Time	12 Hr
Yawing	Free Yaw
Airfoil	NACA 63215
Total Nacelle weight	80 kg

Twenty meters above the ground, the blade was put to the test. The height was chosen based on the fact that small businesses like tool shops, small textile units, and homes don't tend to be taller than 5 meters.

The three blades that were looked at have an aerofoil shape that is NACA 63215, with a blade curve and a twist angle of 6 degrees. Each blade is 2 meters long and weighs 4.2 kg. The wind turbine's specs can be found in Table 1.

TECHNICAL ANALYSIS

Momentum Theory

The rotor axis of the wind turbine is usually not aligned with the wind. Since the wind changes its direction continuously, and the turbine is subjected to yawing. The angle of attack on each blade changes as it rotates and so the loads on the rotor blades also fluctuate. Rotor axis is held at an angle of Yaw ‘γ ‘ to the steady wind. The yaws that were taken into consideration are 10,30,50,60. The axial induction factor ‘a’ as given in (Eq 1) is the fractional decrease in wind velocity between the free stream and the rotor plane,

$$a = \frac{\cos \square}{3} \qquad (1)$$

The power coefficient developed by the rotor at the given yaw angle is given in (Eq 2) $Cp = 4a (\cos\gamma - a)^2$ (2)

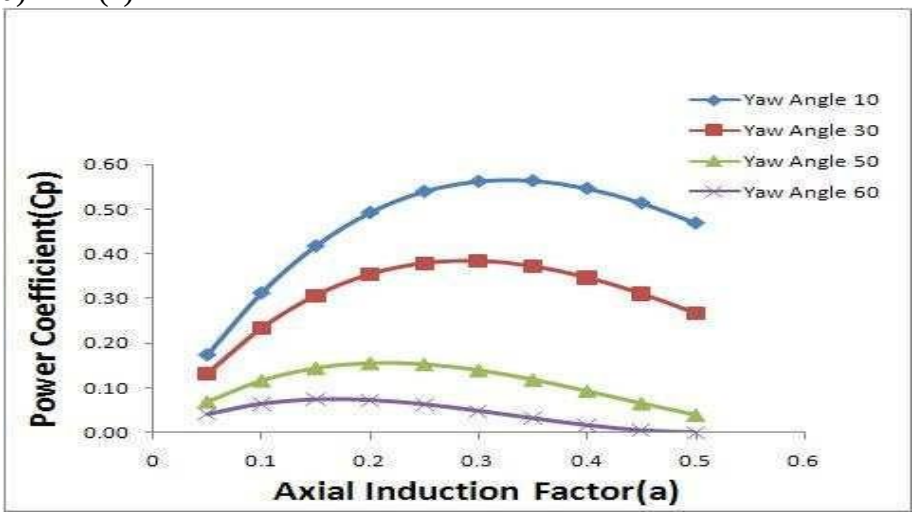


Figure 1: Relationship between Power Coefficient and axial Induction Factor

For the range of yaw angles, it was found that the angle stayed within these ranges for the most part of the time through observation and measurement. (Figure:1) shows the different Cp values that were found for axial induction factors. At first, the power coefficient is very high for turbines with low yaw. It goes up and peaks at a number of about 0.3 for the axial induction factor. After that, it slowly goes down.

The theoretical power developed based on the wind due to the variation of wind velocity for various axial induction factors is estimated using the formula given below in (Eq 3).

$$P = \frac{1}{2} \rho A U^3 4a (1-a)^2 \quad (3)$$

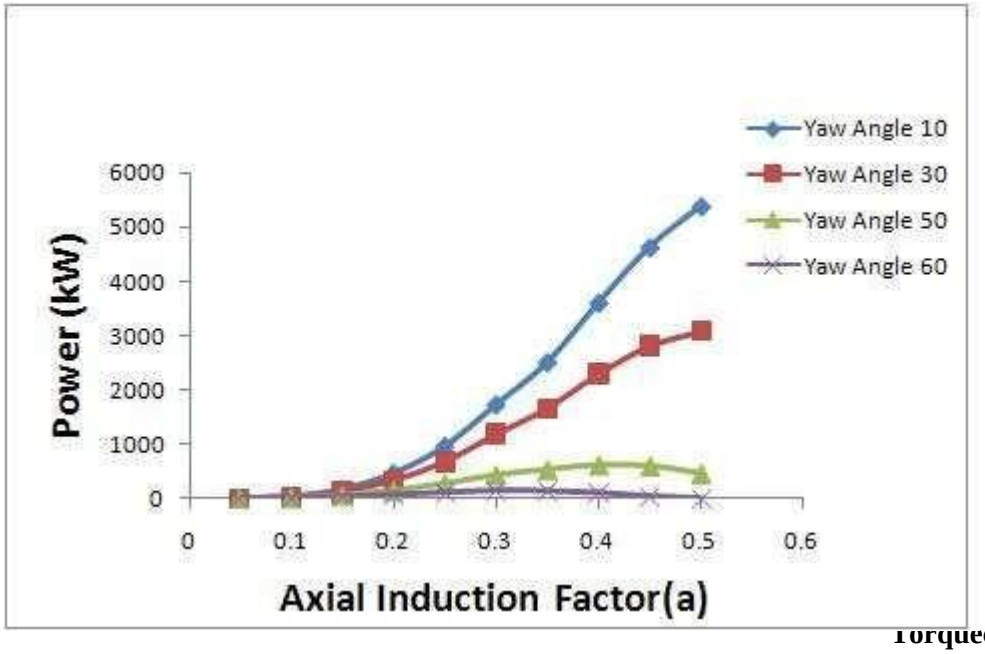


Figure 2: Relationship between Power developed(kW) and Axial Induction Factor(a)

The amount of power that wind mills produce at different yaw angles is shown inWhen the pitch angle is low, the wind machine makes a lot of power. While the angle of Yaw goes up, the wind turbine's power output goes down. When the yaw is 50 or 60 degrees, the power goes up until a certain point and then goes down.

Nacelle Setup

The findings of Baku M. Nagai [6] show that the Nacelle weighs 185 kg and has a changeable pitching system that works well in Japan to handle the high wind speeds that can happen during typhoons and strong gusty winds on a small island surrounded by water. India doesn't have typhoons or strong gusts of wind like that in most of the country. In this case, the Nacelle's weight has been lowered to 80 kg without the gearbox and control mechanism. A yawing mechanism has been added and tested with the main goal of making wind power more accessible to small users and lessening their reliance on power from the government, which goes out often. When measuring wind speed, an anemometer was used. To measure rotor speed, an optical sensor was used. A wind vane was used to measure wind direction, and an optical encoder was used to measure yaw direction.

Generator System

The Generator system used in this study consists of a Variable speed induction motor, PMG generator, Rectifier, Battery, Inverter, and a Load.

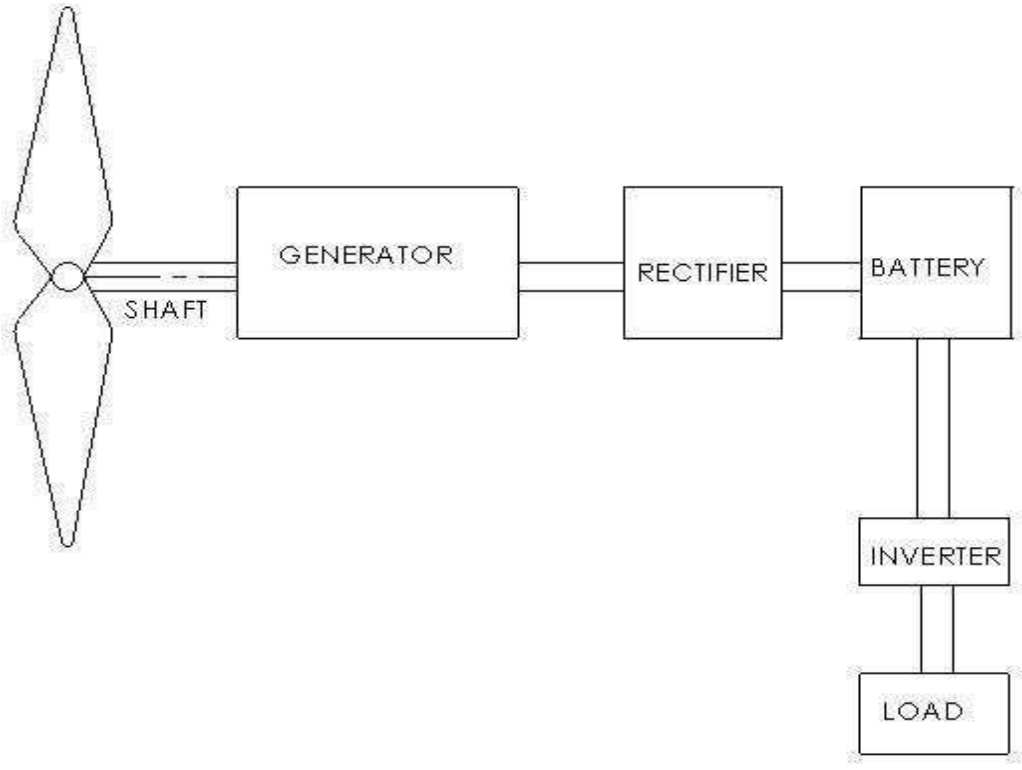


Fig: 3 Wind Power Generator System

(Fig 3) shows the outline of the generator system. The Turbine Blades are connected to the Generator through a shaft. The maximum Output from the generator could be 220 V AC which is fed into the battery, has a specification of 12V 150Ah 12PC. Rectifier converts variable AC to Constant DC. The charge from the batteries is transferred to the load after passing through an Inverter which converts constant DC to variable AC. The copper wires inside the generator are star connected, which has a diameter of 1.02mm. The length of the winding is 70mm. Number of turns is 130. So, the total length of the wire is 9.1 metre.
The resistivity of the wire per metre is 1.25 Ω. Frequency is 50 Hz. The number of poles is 18. The rated speed of the generator was found using (Eq 4) given below

$$N = \frac{120 * f}{Po} \quad (4)$$

Table: 2 Relationship between Speed and Voltage generated

S.No	Speed(N) rpm	Voltage Single Phase	Voltage Three Phase
1	50	12	36
2	100	24	72
3	150	45	135
4	200	67	201
5	250	72	216
6	300	83	249
7	350	102	306
8	400	115	345
9	450	127	381
10	500	153	459
11	550	210	630

The actual values of speed(N) reaches higher values than the theoretical estimated value and given in (Table 2).

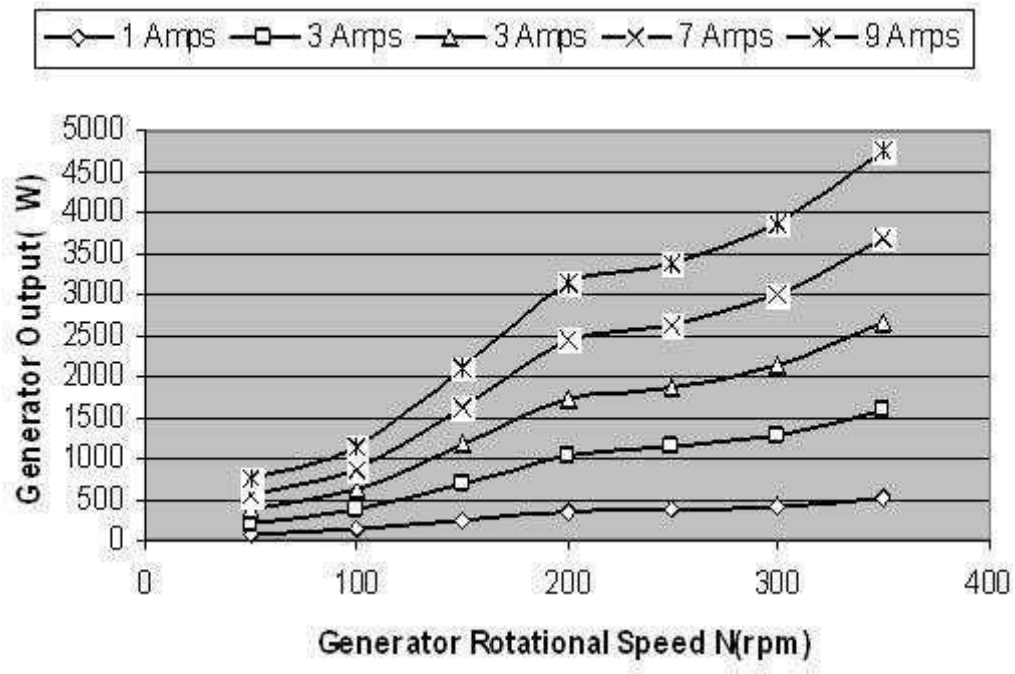


Fig: 4 Relationship between speed (rpm) and power output (W)

The relationship between rpm and power output is given for various values of Amphere currents are given in (Figure 4).

Load Usage

The output of a generator with 220 Volts is corrected and sent to DC loads with a heat resistance of 3 kW and 12 Ohms. A data logger was used on a personal computer to record the power that was made at different speeds. The wire material and diameter were chosen so that they could handle a 3 kW

load. The maximum load of 3 kW was used to figure out the ampere value (Eq. 5).

Power (P) = *V * I

A 19-gauge copper wire that could handle up to 10 amps was used to meet the ampere code. As the blade turns, so does the hub and the shaft that is linked to it. This shaft is tied to the generator and turns as well. The generator sends out AC current that can change. And a rectifier is used to change the direction of this AC current. The result is a steady DC current, which is sent to a battery to be stored. The inverter is linked to the battery and takes the steady DC current from the battery and changes it into changeable AC. The Load is then hooked up to this changeable AC.

Economic Analysis

The study was done in the Coimbatore industrial area, which is known as the "Manchester of South India" because it has so many textile mills and factories that make textile machines. It is helpful that Tirupur is close by. Tirupur is a famous cloth export city with a lot of small businesses. Figure 5 shows the usual speed of the wind in the area.



Figure: 5 Relationship between mean monthly wind speed at 10 and 20 m height.

To find out how much power is needed to choose the right wind turbine, the basic minimum usage of small industrial units and rural/urban family units is worked out. The results are shown in Table 3. And the units used were found using the equation (Eq. 6) below.

$$\textbf{Number of Units Consumed} = \frac{\textbf{Wattage of appliance}}{1000} \times \frac{\textbf{Time taken in mins}}{60} \quad (6)$$

Table: 3 *Basic Minimum Consumption in a Rural House Hold/Day*

Appliances	**No of Units**	**Watts/ Hr**	**Hrs/ Day**	**Units/ Day**
TUBE LIGHT (Electronic Choke)	2	36	4	0.288
CEILING FAN / TABLE FAN	2	60	12	1.44
ELECTRIC IRON	1	750	0.5	0.375
RADIO / TAPE	1	50	2	0.1
COLOUR TV	1	80	3	0.24
WATER PUMP 1/2 HP	1	375	0.5	0.187

Total Units Consumed/Day = 2.6

Details about the power consumption, annual sales of electrical appliances for rural/urban houses, population growth and urbanizations are shown in Appendix Tables 5, 6 and 7.

Table: 4 *Basic Minimum Consumption in a Urban Household*

Appliances	**No of Units**	**Watts/ Hr**	**Hrs/ Day**	**Units/ Day**
TUBE LIGHT (Electronic Choke)	2	36	4	0.288
CEILING FAN / TABLE FAN	2	60	12	1.44
ELECTRIC IRON	1	750	0.5	0.375
RADIO / TAPE	1	50	2	0.1
COLOUR TV	1	80	3	0.24
WATER PUMP 1/2 HP	1	375	0.5	0.187
FRIDGE 165 LTRS	1	100	24	2.4
ROOM Air Conditioner 1.5 TON	1	2100	8	16.8
COMPUTER	1	100	4	0.4
MONITOR	1	100	4	0.4
WASH M/C FULLY - AUTO	1	320	1	0.32
INSTANT GEYSER	1	3000	1	3
MIXER SMALL	1	250	0.5	0.125

Total Units Consumed/Day = 26.1

Table: 5 *Basic Minimum Consumption in a Small Business Unit*

Appliances	**No of Units**	**Watts/ Hr**	**Hrs/ Day**	**Units/ Day**
TUBE LIGHT (Electronic Choke)	2	36	19	1.36
CEILING FAN / TABLE FAN	2	60	19	2.3
WATER PUMP 1 HP	1	750	1	7.5
EXHAUST FAN (INDUSTRIAL)	1	750	19	14.3
SEWING M/C CLOTH	1	100	19	1.9
SEWING M/C REXIN	1	750	19	14.3
COMPUTER	1	100	8	0.8
MONITOR	1	100	8	0.8
PRINTER	1	50	8	0.04

FAX / TELEX	1	250	19	4.75
PHONE ANSWER MACHINE	1	100	19	1.9

Total Units Consumed/Day = 50

The information in Tables 3, 4, and 5 makes it clear that small manufacturing units use the most power. The next least common type of home is one in a city. The most hours that can be worked in the small business unit is 19. Since then, the power will go out and the electricity will be low for 5 hours a day. During this time, the machines would not be able to be used and would be left alone. The amount of tools in each home, whether it was in a city or a country area, was based on a thorough study of how they were used.

4.1Analysis of the power needs of small businesses and homes in rural and urban areas.

1)How much it costs to do business with only the Government Electricity Board:
Total cost of electricity and business loss: Rs.3,31,500 [Appendix]

How Much Does It Cost to Run a Business with Electricity from the Government Electricity Board and Wind Turbines? The initial investment is returned after 2.4 years, and every year after that, Rs.2,71,596 could be saved.

c)Low-Cost Ways to Power an Urban Home with Power from the Government Electricity Board and Wind Turbines: The Rs.4,50,000 invested will pay off in 14.26 years.

• How much it costs to power a country home with electricity only from a wind turbine:
In a country home, the 3 kW of power that comes from wind is not fully used. Even if a 1 kW wind machine is put up in a country home, it is still not cost-effective. Since it will pay for itself in more than 50 years. Expense arrival details for 4.1 (a), (b), (c), and (d) can be found in Appendices 4.1.1, 4.1.2, 4.1.3, and 4.1.4, in that order.

ELECTRIFICATION POTENTIAL THROUGH SMALL WIND TURBINES

A technological and economic study of small wind turbines is done for the Coimbatore area in western Tamil Nadu. There are a lot of small and medium-sized textile businesses in and around Coimbatore. There is a big need for power in these places. This area often loses power because there is too much demand and not enough supply. Wind power could be a good way for these small cloth and industry units in this area to get the power they need. A lot of people in cities could use small wind machines, not just in factories or other small buildings. At 20 meters above ground, these small businesses and homes on the edges of the city have a lot of wind that could be used. The average height of a person living in this area will not be more than 5 meters. Putting a small 3kW engine 20 meters above these homes or near the factories might not be hard. This was tried in a small textile unit that uses sewing machines to make clothes and rexins.

CONCLUSION

The Census of India says that by 2026, India will have 1.4 billion people living in it. The rate of people living in cities is expected to rise from 29% in 2006 to 33% in 2026. If you extrapolate this trend, the rate of urbanization will be almost 35% by 2031. More people living in cities means more high-tech electrical tools being used at home and a huge rise in the amount of power used per person. There will be a huge need for power because of this. The country gets its power from a

number of different sources. One of them is wind power. Most people these days use big wind machines, and big businesses use the power they make. But wind power has a huge amount of promise to be used in other places, like small factories and homes in both urban and country areas. It has been tried to see if small wind mills can be used and if they are economically viable. The return on investment for small businesses is 2.4 years, for homes in cities it is 14.26 years, and for homes in the country it is more than 50 years. Small wind farms are the most cost-effective way for small businesses in India's cities to power their operations.

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