



# Optimization grid tied rooftop micro wind turbines in low wind speed regime

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## 1. ABSTRACT

The major problems with grid tied micro wind turbines is synchronization and wind variability. Due to these problems the stability of available grid gets reduced. This can be achieved by output power control of the turbine. In our grid tied wind turbine, the annual mean wind speed is not high. The rated wind speed of turbine, remain around 11 m/s and cut off are around 5.5 m/s. Due to this problem we are aimed to develop a sustainable wind energy system that can provide stable power supply even at the lowest one of low wind speed of 2-4 m/s. To address this issue a momentary impulse or external torque to the rotor by external motor is good option to maintain the momentum of blades and thus provide stability in sufficient time. Various theoretical calculations and experiments are conducted on the above suggested method. This would increase the output power and also the efficiency of wind turbine. This implies that Return-On-Investment will be high as compared with other grid connected turbines. Our proposed concept in the present study can increase the number of turbines even at domestic level. It helps to make the consumer energy independent and promotes the use of wind as a source of energy and may enter as a rooftop energy supply systems similar to solar.

## 2. INTRODUCTION

Wind energy development is picking up as a part of electricity generation in different parts of India. Although it was initiated a decade back, still there is enough scope for its improvement in this technology. Of the installed capacity, wind turbines take a large share among the other grid connected renewable sources, about 66.6%. Obviously wind turbines need to be built where the wind blows steadily and strongly. Accordingly, we must build sustainable energy supply systems. Solar or water powered wind energy is more safe [1]. In our study we have started on grid tied rooftop micro wind turbine. The major problem with such a system is synchronization largely due to wind variability. Due to the problem, the stability of available grid gets reduced. This can be achieved by the output power control of the turbine. India is rich in high rated wind power potential in the world. As of March 2014, the installed capacity of wind power in India is 21,136.3 MW [2], nearly spread across Tamil Nadu (7,154MW), Gujarat (3,025MW), Maharashtra (2,964MW), Karnataka (2,113MW) and Rajasthan (2,883MW). Wind power accounts for 5.5% of India's total installed renewable power capacity and it generates 1.6% of the country's power. Still it is not that popular at domestic level due to the high initial investment and other problems as discussed above. Our goal is to achieve stable power supply to the grid from wind source. To this issue, we suggest the method of small external motor which will provide momentary impulse or external torque to the rotor through this motor. It is better consider that height is maintain, the momentum of blades for sufficient time and provide stable power supply. The concept presented in this paper is implemented and a few photographs of the installation are shown in figures 10, 11 and 12.

## 3. MATERIALS AND METHODS

In our method, we attached an external motor to the turbine rotor that provides sufficient external torque to the rotor to start at its rated rpm when the wind speed is less than the rated speed so that the wind generator can produce a stable and power supply.

### 3.1 Theory

It is well known that the amount of power extracted from the wind is given by the equation:

$$P_{\text{Total}} = 70 \rho A V^3 C_p / 10^6 \dots (1)$$

$$P_{\text{Generator}} = 70 \rho A V^3 C_p C_g C_t / (p \cdot 2) P^{\text{rated}} \dots (2)$$

$$\text{Tip Speed Ratio}(\lambda) = \omega R / V \dots (3)$$

$P_{\text{Generator}}$  = Power Delivered to the wind rotor before the rated value  
 $P_{\text{Generator}}$  = Output Power of the generator  
 $C_p$  = Power Coefficient,  $C_g$  = Transmission Coefficient  
 $C_t$  = Generator Efficiency,  $p$  = number of poles in Generator

Motor supply sufficient torque to the rotor so that generator operates at rated power. The following is the mathematical condition:

$$T_{\text{Total}} = T_{\text{Motor}} + T_{\text{Generator}}$$

$$P_{\text{Motor}} / \omega_{\text{Motor}} + P_{\text{Generator}} / \omega_{\text{Generator}} = P_{\text{Total}} / \omega_{\text{Total}}$$

Using equation (1) & (2):

$$P_{\text{Motor}} = \frac{70 \rho A V^3 C_p C_g C_t}{p \cdot 2} P^{\text{rated}} - V^3 \omega_{\text{Total}} \omega_{\text{Generator}}$$

For the above suggested mechanism to be useful, the generated power should be greater than the power supplied by the motor:

$$P_{\text{Generator}} > P_{\text{Motor}}$$

$$V^3 \omega_{\text{Total}} C_g C_t / (p \cdot 2) > R \omega_{\text{Generator}} (V^3 \omega_{\text{Total}} - V^3 \omega_{\text{Motor}})$$

In our study, SHT-1, 700W micro grid tied turbine is used. Its parameters are,  $N_{\text{rated}}$  = 11 m/s (according to industry standards),  $C_p$  = 5.0 (since no gearbox system is used),  $C_g$  = 0.25 (assumed to be constant for easier calculation),  $C_t$  = 0.25 (assumed to be constant),  $p$  = 8,  $R$  = 900mm,  $N_{\text{rated}}$  = 2 m/s,  $P_{\text{Generator}} = 70 \text{ rpm}$ ,  $P_{\text{Generator}} = 8 \text{ Watts}$ .

SHT-1 turbine is already designed for maximum rotational speed of 300 rpm at a wind speed of 6 m/s. So,  $T_{\text{SP}} = 4.05$  (assumed to be constant for easier calculation). Above the wind speed of 6 m/s, it dampens extra energy to the dummy load.

Accordingly, the calculations have been carried out considering the wind speed of 5 m/s as rated. Another reason for this is that the generator is not designed for higher wind speeds.

## 4. RESULTS

### 4.1 Theoretical Results:

Following are the results observed by calculating using theoretical considerations. Following are the results to power available to the rotor at rated 6.8m/s wind speed (Fig.1)



Fig.1 Available Rotor Power at various wind speeds

Following is the plot of external torque to be provided by motor to achieve the rated rpm (Fig.2). Maximum torque that can be provided by our installed DC Motor is 2.45 N-m. In the figure green region corresponds to desirable region of operation and red region corresponds to undesirable operational region.



Fig.2 Torque to be provided by external motor at various wind speeds

### 4.2 Experimental Results:

However in a controlled wind tunnel on a test bench of SHT, a SHT motor is used to make the shaft of 400W generator. The results obtained are contradictory to our theoretical results. We obtained power consumed is greater than power generated for every value of generator rpm. However, this is not our intention to do, because, the extra energy to start the generator shaft is provided by motor in this case. In our method, extra energy could be provided by the wind. Experimental results using external motor without wind are as shown below (Fig.3&4).



Fig.4 Power Consumed by motor at various rotor RPM



Fig.5 Power Generated at various rotor RPM

### 4.3 Power Generated and Consumed at live wind speed

Following results are obtained on comparing power generated and power consumed for live wind speed data:



Fig.6 Power Generated and Consumed at live wind speed. Above results clearly show the gain in power by our discussed method. Hence our method is being partially established.

## 5. CONCLUSIONS

We have addressed a few issues related to wind turbines and suggested solutions for the same. Hopefully our suggested method will yield into a product that would help changing the wind power scenario at domestic level. SHT-1 wind turbine installed on rooftop of our energy building, GERMI at PGPV campus, is specially designed for low wind speed regime and for the first time designed and installed a grid tied rooftop micro wind turbine. Further improvement is needed to reach to a level to work on concrete proof. We need to test our suggested methods usefulness to the society as well as the industry. In this aspect, more extensive experiments could be devised with state-of-the-art facilities. The wind braking and rotor system will be upgraded and automated in near future for better results. A control system could also be attached which allows remote generator to grid when the grid supply is off. During the season, when wind velocity is far enough, our method can be a real asset at least for rooftop wind turbines.

## 6. REFERENCES

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## 7. ACKNOWLEDGEMENT AND CONTACT

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 Dr. Sankaranarayanan, Scientist C, Solar Research Wing, GERMI, for his valuable support and technical guidance during the course of the project.  
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 Mr. NVG Manoj Tejuskar, my fellow researcher, Renewable Energy Research Wing, GERMI, for assisting and helping me in my experiment and theoretical research work.  
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