Introduction of Car Alternators for Small Scale Wind Power Generation

Soysa. WHID, Peiris. LR, Perera. LAAN, Sandagiri. CA, Siriwardena. KAP

Supervised by: Dr. Nanayakkara D.P.N

Department of Electrical Engineering, University of Moratuwa, Sri Lanka.

Abstract: **Generally Permanent Magnet Generators (PMGs) are widely used for small-scale wind power generation. But in Sri Lanka, it is difficult to find a competitive market for such generators and permanent magnets, since the price of a PMG is very high and is very rare.Due to such conditions, expansion of small-scale wind power applications among rural communities are significantly limited. The introduction of widely available car alternators is expected to break through the boundaries of limited expansion of small scale wind power generation due to its low cost and reliability.**

I. INTRODUCTION

According to the current grid expansion of Sri Lanka, only 55% of people have the accessibility to the national grid. Therefore the rest of the people have to suffer from the dark or they have to obtain the assistance of an alternative source. It is a well known fact that a large amount of the people suffering from dark have selected kerosene oil lamps as their light source and some rural communities utilize more than 550,000 of car batteries. Electrifying them with the national grid supply would not be so economical and hence a substitution of a localized source will be more suitable. Under such sources solar, hydro and wind are the major contributors, but hydro potential is limited to the central part of the country and the solar photovoltaic is not yet cheaply exploitable. Therefore the wind energy conversion can be cheaply exploitable in many rural Oceanside areas.

Due to the existence of conventional PMG in the models developed by NERD and ITDG for small-scale wind applications, their cost is very high. Hence the research is going on to optimise the cost for a small-scale windmill, by introducing widely available car alternators.

The research is to develop a model at a competitive price and achieving increased performance by replacing the traditional PMG with widely available car alternators for small-scale power generation. The developed model consists of complete control functions, assuring reliable and efficient operation, including an inverter circuit for the accessibility of ac loads like CFLs, colour TV etc. consequently increase the living status of rural communities.

Due to the introduction of a car alternator, there will be several modifications. They are, replacing conventional two bladed rotor with a three bladed rotor of 2.3m of diameter, a transmission system to couple the turbine and the generator, generator excitation controller to avoid battery draining at low wind speeds, battery discharge controller and inverter for ac loads, electrical dump load breaking of the alternator when the battery is fully charged (avoids over speeding of the turbine). The work carried out to develop the model will be explained briefly through out the paper. All the experimental data given is found by the development team, and the special control functions like excitation control of the alternator with the cut-in wind speed (avoids battery draining while the system is not generating), dump load breaking on generator at battery fully charged conditions, the battery discharge controller and the 230V ac inverter would be the innovations for small scale wind power generation.

II. ROTOR AND ALTERNATOR PERFORMANCE TESTS

Generally car alternators are high-speed generators, but wind turbines could never reach such high speeds Therefore a gear step up mechanism is needed to ensure the power generation with a car alternator. In this case it is needed to measure the turbine and the alternator characteristics separately, and then matching their characteristics with a suitable gear step up mechanism is required. Here the relationships between the Coefficient of Performance (Cp) vs. Tip Speed Ratio (TSR) and the TSR vs. Wind speed will give a clear picture on the characteristics of the wind turbine. These curves will help to determine the maximum torque generated by the turbine at various TSRs and the speed of the turbine at various wind speeds respectively.

Curves given in figures 1 and 2 show the characteristics of the wind turbine, which are experimentally found with the Band Brake Method.

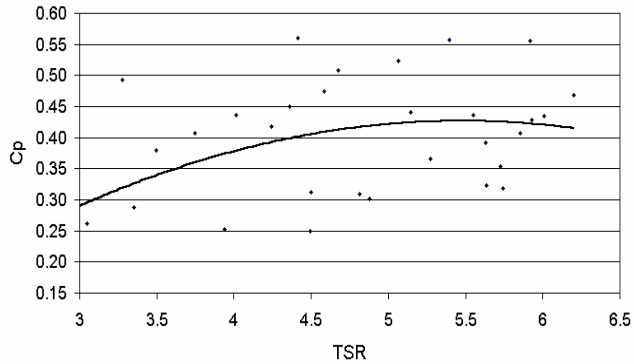

Fig. 1 Coefficient of Performance (Cp) Vs. Tip Speed Ratio (TSR)

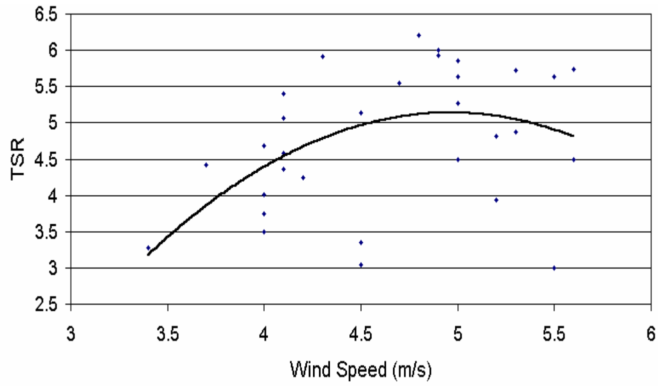

Fig. 2 Tip Speed Ratio (TSR) vs. Wind speed

Car alternators start to generate power as they exceed 800rpm. Generally it has an integrator built in IC regulator to regulate the out put voltage at the battery terminals as the generator speed varies. Car alternators are specifically manufactured for battery charging of the vehicles. Hence the car alternators would be ideal for battery charging applications, but it is needed to have high speeds at the generator. Figure 3 shows the generator Voltage and Current profiles with its speed. (Alternator characteristics are experimentally found with an 80 Ah car battery)

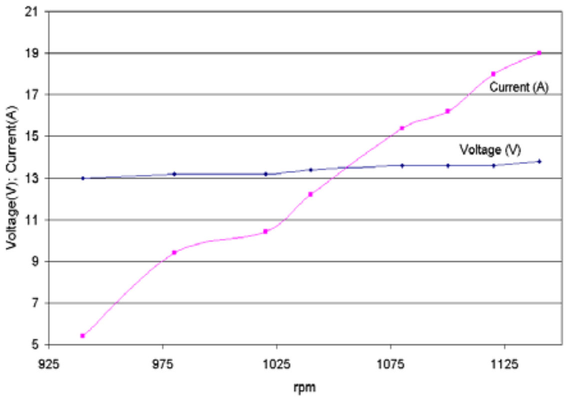

Fig. 3 Alternator Test with IC Regulator

Figure 4 shows the generator input mechanical power requirement and the generated electrical power output at various speeds. (Assuming typical efficiency variation of an alternator is ranging from 50%~ 60%)

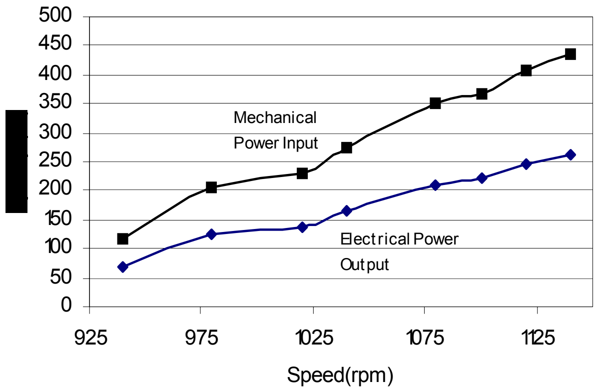

Fig. 4 Mechanical Power Input and Electrical Power Output vs. Speed

A. Matching Characteristics

Matching the characteristics of the rotor and the generator would be the heart of the project. Research is carried out to identify the optimum step up gear ratio practically and the results have been proved theoretically also. The optimum step up gear ratio can be determined according to the data obtained above tests and the ratio should be determined according to the maximum efficiency point of the generator. Further more, the design can be done site specifically to match with the average wind profile. The model Windpro2004 wind turbine could generate *163W*; electric power around wind speed at *9m/s* and the selected gear ratio was *1:4*. The curve in figure 5 shows the matching the characteristics of the turbine and the generator theoretically and practically. Practical matching is done according to the data found experimentally.

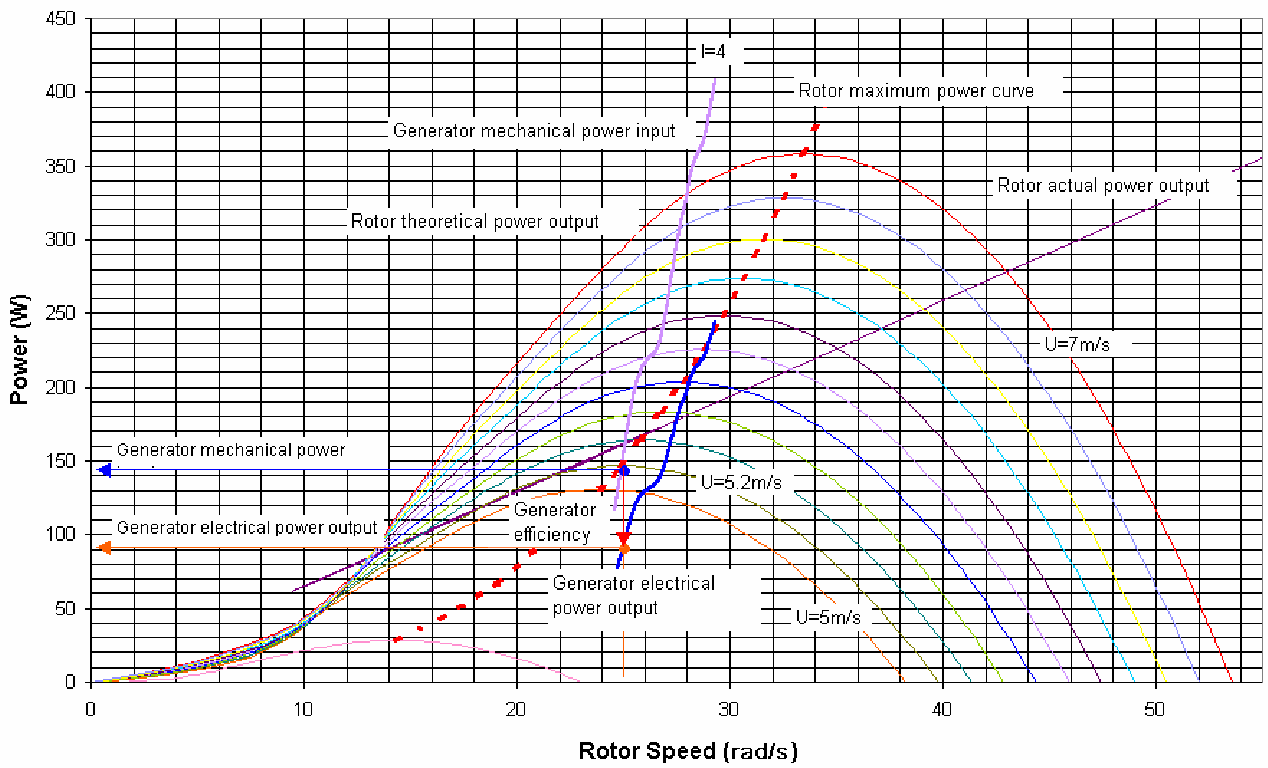

Fig. 5 Rotor mechanical power and generator input/output power as a function of rotor speed

B. Power Performance

Developed model could generate *163W* of electrical power at around *9m/s* wind speed. Design wind speed is *5.2m/s* and the maximum overall efficiency is *0.18* under experimental conditions. Curve in figure 6 shows the Power Performance data found experimentally, during the period of real time monitoring of the plant performance (data logging), with the selected gear step-up ratio of *1:4.*

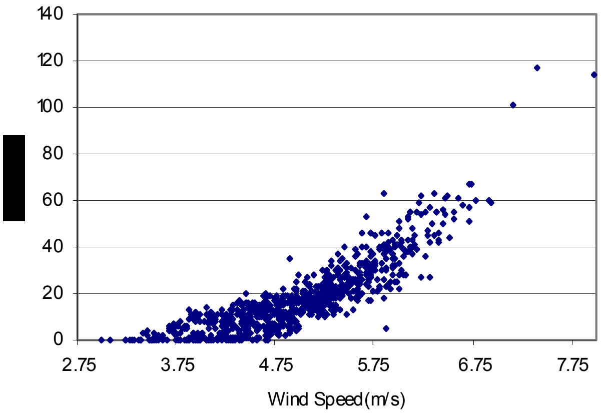

Fig. 6 Power output Vs wind speed curve

III. PLANT ACCESSORIES

Efficiency of the transmission system influences the overall efficiency. Gearbox would be the best, but belt with pulley coupling is economical and have a moderate efficiency. During the experiment it is much easier to use a chain coupling, as it is required to alter the gear ratio frequently.

Yaw mechanism provides the orientation of the rotor, with the aid of tail vane to the direction of the wind flow automatically. Furling activates at high wind speeds by turning the rotor outside to the wind direction. Here the technique behind the furling mechanism is to use an ex-centric rotor to the yaw axis.

A. Control Circuit/ Accessories

Typically alternator starts to generate as it exceeds 800rpm, therefore an excitation supply should be provided as the generator exceeds a pre-determined speed (rpm) preserving the battery draining unnecessarily. The field controller circuit automates this function. In addition to that, a braking system is activated automatically as the rotor exceeds the safe rpm level when the battery is fully charged. The principle behind that would be the dynamic braking of the generator with a resistive dump load. In addition to that, research would intend to introduce an inverter to enhance consumer living status and productivity with considerable welfare benefits (lighting, entertainment etc.).

IV. DATA LOGGING SYSTEM

During the research work a special data logging system is developed to verify plant performances at various step-up gear ratios. Data logging software 'DatLog' is developed using Microsoft Visual Basic as the key language and the hardware interface is designed while ensuring the capability of fast real time data communication through the parallel port of the PC. Software possesses the features such as Real time monitoring of Wind speed, Rotor rpm, Battery voltage, Battery Current and also it includes a power full data base with 10 min. average of the above quantities and on line plots and reports of plant performance data. The research further facilitates data logging capability with a PC of the plant, to verify overall efficiency, plant factor and the energy conversion factor while determining the feasible region. Complete system block diagram of the developed wind turbine is given in figure 7 including the data logging interfaces.

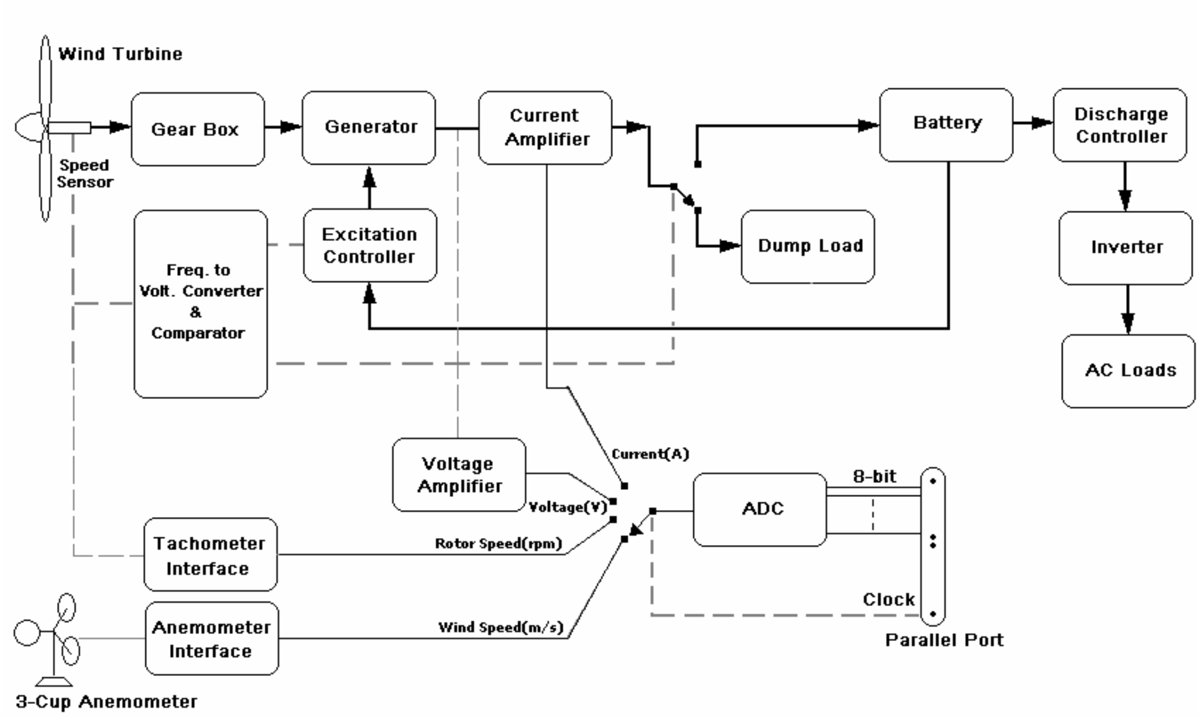

Fig. 7 Block Diagram of Windpro Wind Turbine

V. CONCLUSION

According to the performance results of the turbine obtained during data logging period, it is obvious that the developed wind turbine with the introduction of a car alternator would be a technically feasible, economically viable and environmentally compatible substitution for small-scale wind power generation. Under the experimental conditions this wind turbine could generate *18.75 kWh* per month at *4.8m/s* of average wind speed. With further developments of the generator stator winding, coupling with high TSR turbines and with a higher efficient transmission system electrical power out put can be significantly increased, consequently increase of annual power generation and reduction of cost of the wind turbine.

REFERENCES

[1] Desire Le Gourieres, Wind Power Plants Theory and Design, 1982 pp 175-185

[2] Simon Dunnett, Smail Khennas and Hugh Piggott, Small Wind Systems For Battery Charging, 2001

[3] Sunith Fernando and Hugh Piggott, Wind Rotor Blade Construction, 2001

[4] Hugh Piggott, Blade Carving Manual, http://homepages.enterprise.net/hugh0piggott/selfblade/index.html

[5] Hugh Piggott, The Permanent Magnet Generator (PMG), 2001

[6] Walter E. Billiet, Leslie Goings, Automotive Electrical Systems, 1970 pp 191-223

[7] National Semiconductor, Op Amp Circuit Collection, Application Note 31, September 2002

[8] www.maxim-ic.com/application notes

[9] Web resources for hybrid systems

[10] ITDG, Energy from the Wind, Technical Brief