1.8 metre diameter wind turbine blades and generator

Abstract

A 2kW 1.8 metre diameter wind turbine was designed and constructed out of carbon fibre and generator built by converting an induction motor into a permanent magnet generator, the wind turbine blades power and efficiency has been measured at different tip-speed-ratios, maximum efficiency at TSR of 11.6, 30% efficiency, verifying the blade calculators accuracy. Total cost of the generator and blades was less than AU$200

Keywords: Wind power, Permanent Magnet Generator, 2kw wind turbine

LIST OF FIGURES

1. Construction of the Permanent Magnet Generator

Design of a permanent magnet generator was necessary to test and characterise the blade set, conversion of a 40 amp car alternator to a permanent magnet generator was attempted.

Figure 1. 40 amp car alternator rotor with magnets attached

The alternators rotor was turned down on a lathe to accommodate neodymium magnets, six magnets were carefully place on a slight angle to reduce cogging of the generator.

Figure 2. 40 amp car alternator rotor with magnets fibre glassed in place

The magnets were fibre glassed in place with two strips of carbon fibre.

Figure 3. 40 amp car alternator stator with shielding

Sheet metal was placed inside the stator to shield the magnetic field from aluminium, without the sheet metal significant power was lost in the aluminium.

Figure 4. Completed conversion of the 40 amp car alternator

Power output was measured to be less than 500 watts at the designed blade rotational speed. The generator will not produce enough power for the 1.8m diameter blades, it is more suited to 1.0m diameter blades with a high tip-speed-ratio.

The same technique was used to convert a larger ¼ hp induction motor into a 8 pole / 3 phase PMG

Figure 5. Completed conversion a ¼ hp induction motor

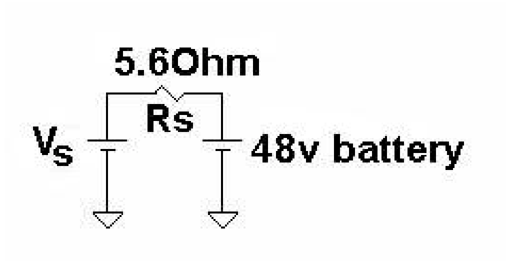
Power output was measured to be more than 2000 watts at the designed blade rotational speed. The generator has enough power for the 1.8m diameter blades, the generator has zero cogging, this is due to the angled magnets and the 2mm air gap between the rotor and stator, the generator is configured for 3 phase, each phase measuring 5.6 ohms. Output voltage is 130Vrms at 1333rmp increasing linearly with rpm.

2. Calculating generator efficiency

given:

1. the 3 phases are isolated, and connected as 3 single phase outputs
2. each output is rectified to DC using a single phase bridge rectifier.

At 666rpm, generator voltage Vs = 65Volts,



R_s = resistance of each phase of the generator (5.6 Ohms)
Voltage across R_s = 65 - 48 = V_s = 17 Volts

V = IR

V/R = I

Current into battery = 17/5.6 = 3 amps per phase

P = VI

Power into battery = 48 x 3 = 144 watts per phase
(432 watts for all 3 phases)

$P = V^2/R$
Power Lost = $17^2/5.6$ = 51.6 per phase

Efficiency of generator = 144/(144+51.6) = 73.6%

3. Design and construction of the wind turbine blades

The wind turbine blades were designed using the warlock engineering blade calculator program, the airfoil chosen was NACA2412, two blades were designed to have a tip-speed-ratio of 10.

Figure 6. Wind turbine airfoil cross-sections

The airfoils cross sections were cut out of 3mm aluminium sheets, the sheets were bolted to a steel frame and aligned.

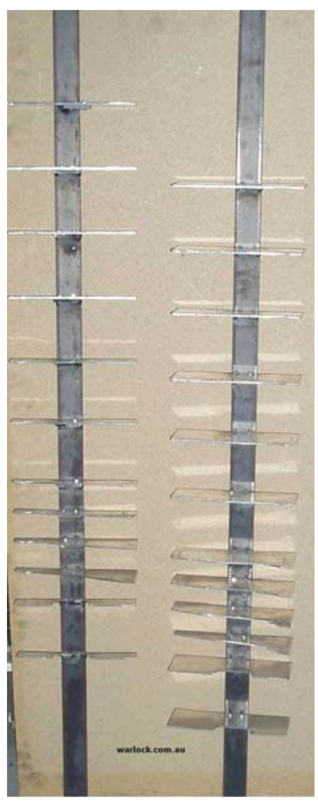


Figure 7. Wind turbine airfoil cross-sections bolted to frame

The gaps between the airfoil sections were filled with aluminium tape, and the back of the tape was fibre glassed in place. Wax and mould release was applied to it and two positive moulds were made.

Figure 8. Positive moulds of wind turbine blades

The moulds were sanded down using the aluminium impressions as a guide, Wax and mould release was applied to the positive moulds and new negative moulds were made out of fibreglass and carbon fibre

Figure 9. Negative moulds of wind turbine blades

Detailing of the positive mould produced a perfect negative mould, this final negative mould was waxed and mould release was applied to it. 220g CSM fibreglass with vinyl ester resin was applied to each mould, the two mould halves were clamped together after the resin had gelled, and the blade was removed after cure.

Figure 10. 1.8 m blade set

The blades were sanded and carbon fibred, using an additional layer of carbon fibre around the hub section, the blades are extremely light weight.

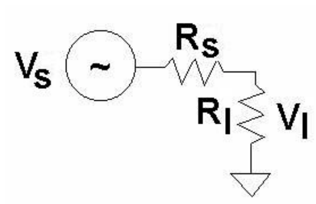
4. Testing the wind turbine

Wind turbine was bolted to a trailer and rpm, voltage and tsr was measured by connecting the generator to a very high power multi-tap resistor, The turbine was allowed to speed up to an open circuit voltage of 65v (666rpm) before the resistor load was connected.

Figure 11. Turbine testing

5. Measured results the wind turbine

Note: Method of testing turbine generates turbulent wind affecting efficiency, Therefore results should be used as a guide only.



R_s is the resistance of the generator windings plus the power cable; 5.75 ohms
R_l is the resistance of the load; 6.6, 10, 15, 21.5 an 25 ohms

Power generated by the blades was calculated by dividing by the efficiency of the generator,
Once the blades have been characterized, a new generator will be designed

Power generated by the blades are calculated by the following:

Voltage across the resistor load was measured V_l,
$V_s = V_l \times [(R_s + R_l) / R_l]$

Power produced by blades, and lost in generator, power cable and resistor load is given by;

$$P = V^2/R$$

$$P = V_s^2 / (R_s+R_l)$$

	25ohm	21.5ohm	15ohm	10ohm	6ohm
30km/h	820	766	809		
40km/h	1302	1363	851	645	
50km/h	1753	1676	1489	1291	1105
60km/h		2365	2098	1744	1607

Rotational speed (rpm)

	25ohm	21.5ohm	15ohm	10ohm	6ohm
30km/h	208	205	300		
40km/h	524	649	332	252	
50km/h	950	981	1017	1008	940
60km/h		1953	2019	1837	1990

Power (watts)

	25ohm	21.5ohm	15ohm	10ohm	6ohm
30km/h	0.23	0.23	stalled		
40km/h	0.24	0.30	0.15	stalled	
50km/h	0.22	0.23	0.24	0.24	stalled
60km/h		0.27	0.27	0.25	0.27

Blade efficiency

	25ohm	21.5ohm	15ohm	10ohm	6ohm
30km/h	278	260	275		
40km/h	441	463	289	218	
50km/h	595	569	506	438	375
60km/h		803	712	592	546

Tip speed (km/h)

	25ohm	21.5ohm	15ohm	10ohm	6ohm
30km/h	9.2	8.7	9.2		
40km/h	11.0	11.6	7.2	5.5	
50km/h	11.9	11.4	10.1	8.8	7.5
60km/h		16.1	14.2	11.8	10.9

Tip speed ratio

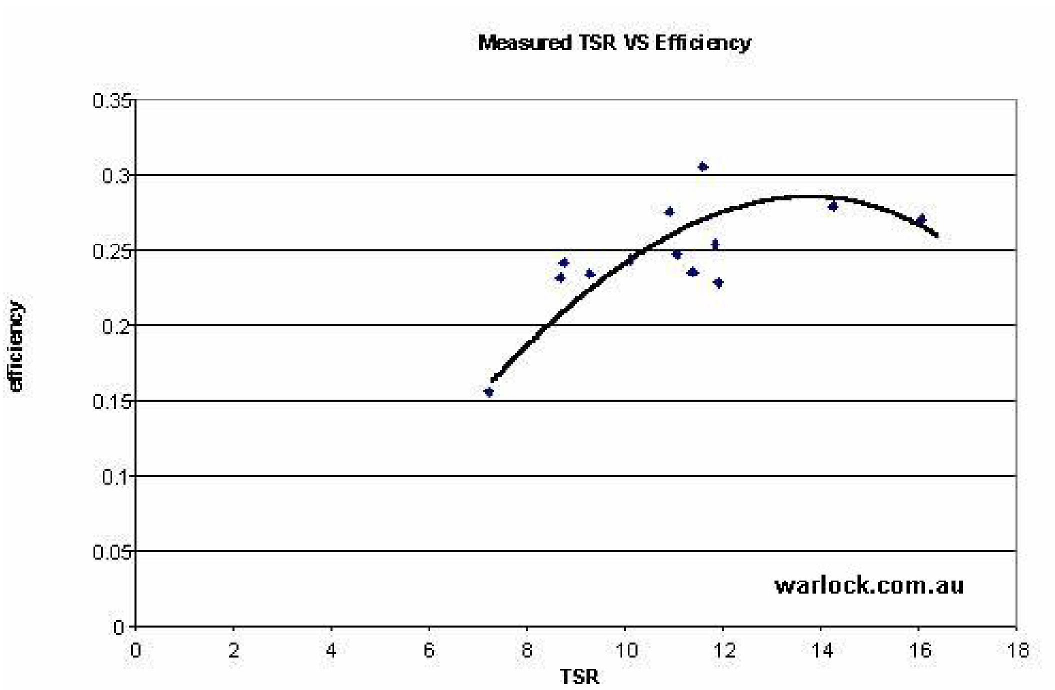


Figure 12

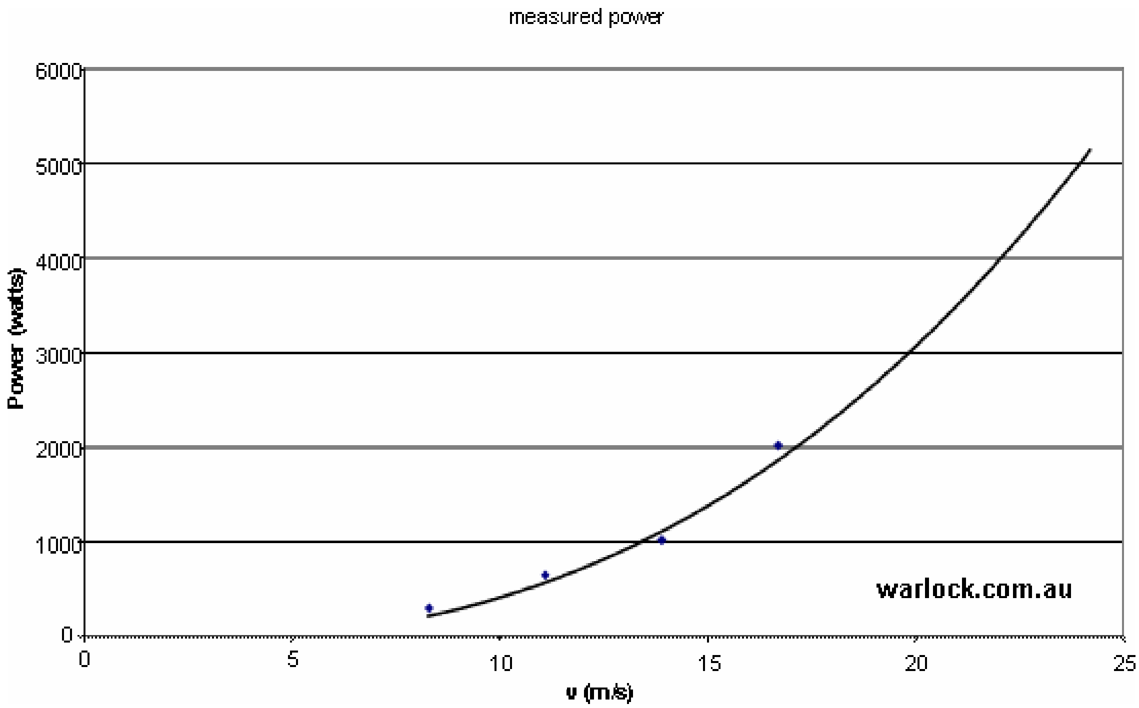


Figure 13

6. Total cost of the wind turbine

System cost (AUD)
Induction motor $15
Magnets $80
Moulds $72
Two Blades $14

Total cost $181

7. Conclusion

Design of highly efficient blades means smaller size blades for same power, Smaller size means higher rpm and higher rpm makes a smaller and cheaper generator.