

Development and Performance Analysis of a Micro Wind Electric Generator

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Agenda

- Small Wind Electric Systems
- Specifications of WEG
- Testing of WEG
- Testing of Alternators
- Performance indices of WEG
- Economic Feasibility Study
- Conclusion

Small Wind Electric Systems

Employ micro wind turbines
(100 W to 50 kW)

Can be standalone or grid connected

Standalone systems- ideal choice for
decentralized rural electrification

Specifications of WEG

Components of Wind Electric Generator (WEG)

- Micro wind turbine
- Gear used as drive
- Generator
- Electrical load

Specifications of turbine

Type: vertical axis savonius

Length: 110 cm

Breadth: 80 cm

Thickness: 36 gauge sheet steel

Length of shaft: 120 cm

Shaft diameter: 15 mm

Bearings: Ball bearings on two ends

Specifications of Generator and gear

Rated capacity of 3-ph alternator: 432 VA

Output is rectified to supply 12 V, 36 A DC

Gear Ratio: 1 :8

Turbine Terminology

Power Coefficient, C_p

= Power extracted from wind

Input wind power

where Input wind power = $0.5 \times \text{density of air} \times \text{area of turbine rotor} \times \text{cube of wind speed}$

Tip speed ratio, λ (radians) = $2 \times \pi \times R / v$

where R = radius of rotor



Testing of WEG unit

Observations at 7 m/s

| Output voltage of Alternator (V) | Output current of alternator (A) | Rotor speed (RPM) |
|----------------------------------|----------------------------------|-------------------|
| 1.0 | 6.5 | 422 |
| 1.5 | 6.5 | 443 |
| 2.0 | 6.0 | 461 |
| 3.0 | 6.0 | 474 |
| 4.5 | 4.5 | 515 |
| 5.5 | 4.0 | 534 |
| 7.5 | 2.5 | 559 |
| 10.0 | 1.5 | 623 |

Observations at 15 m/s

| Output voltage of alternator (V) | Output current of alternator (A) | Rotor speed (RPM) |
|----------------------------------|----------------------------------|-------------------|
| 2.5 | 15.0 | 1335 |
| 3.5 | 14.0 | 1368 |
| 5.0 | 13.0 | 1382 |
| 7.5 | 11.5 | 1399 |
| 8.5 | 10.5 | 1421 |
| 10.0 | 9.5 | 1443 |
| 10.5 | 9.5 | 1554 |
| 12.0 | 7.5 | 1571 |
| 13.0 | 6.5 | 1588 |
| 14.5 | 5.0 | 1604 |
| 15.5 | 3.5 | 1617 |
| 16.0 | 3.0 | 1634 |



Testing of alternator

Losses

Core loss – neglected.

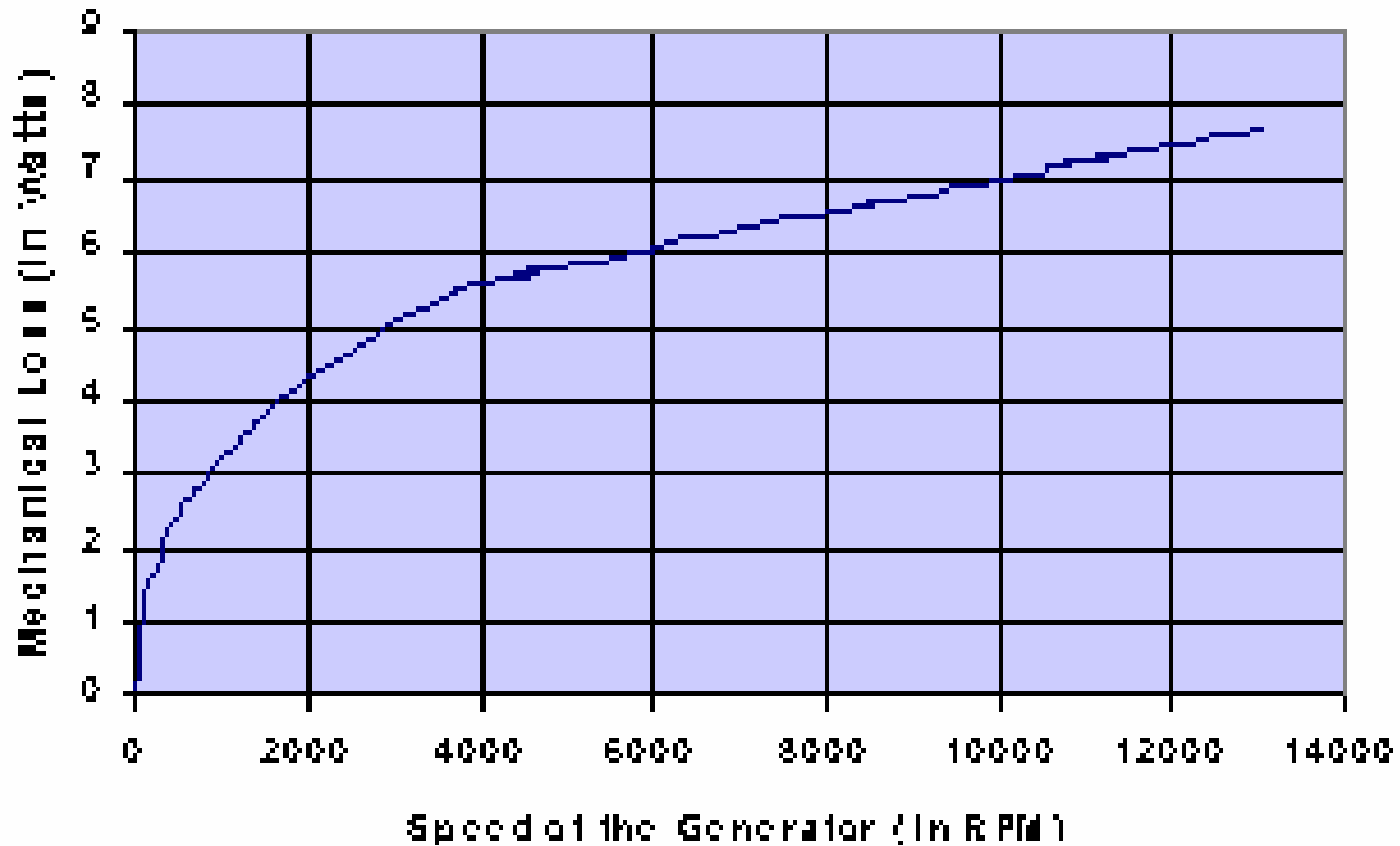
Per phase winding resistance = 0.05 ohm

Alternator was run as a motor to calculate copper losses and mechanical losses at various speeds.

Mechanical loss at various speeds

| Speed Of Alternator (RPM) | Mechanical loss (W) |
|---------------------------|---------------------|
| 100 | 1.4 |
| 200 | 1.6 |
| 300 | 1.95 |
| 400 | 2.30 |
| 500 | 2.54 |
| 600 | 2.65 |
| 700 | 2.78 |
| 800 | 2.88 |
| 900 | 3.08 |
| 1000 | 3.18 |
| 1100 | 3.32 |
| 1200 | 3.46 |

Profile of mechanical loss





Performance Indices of WEG

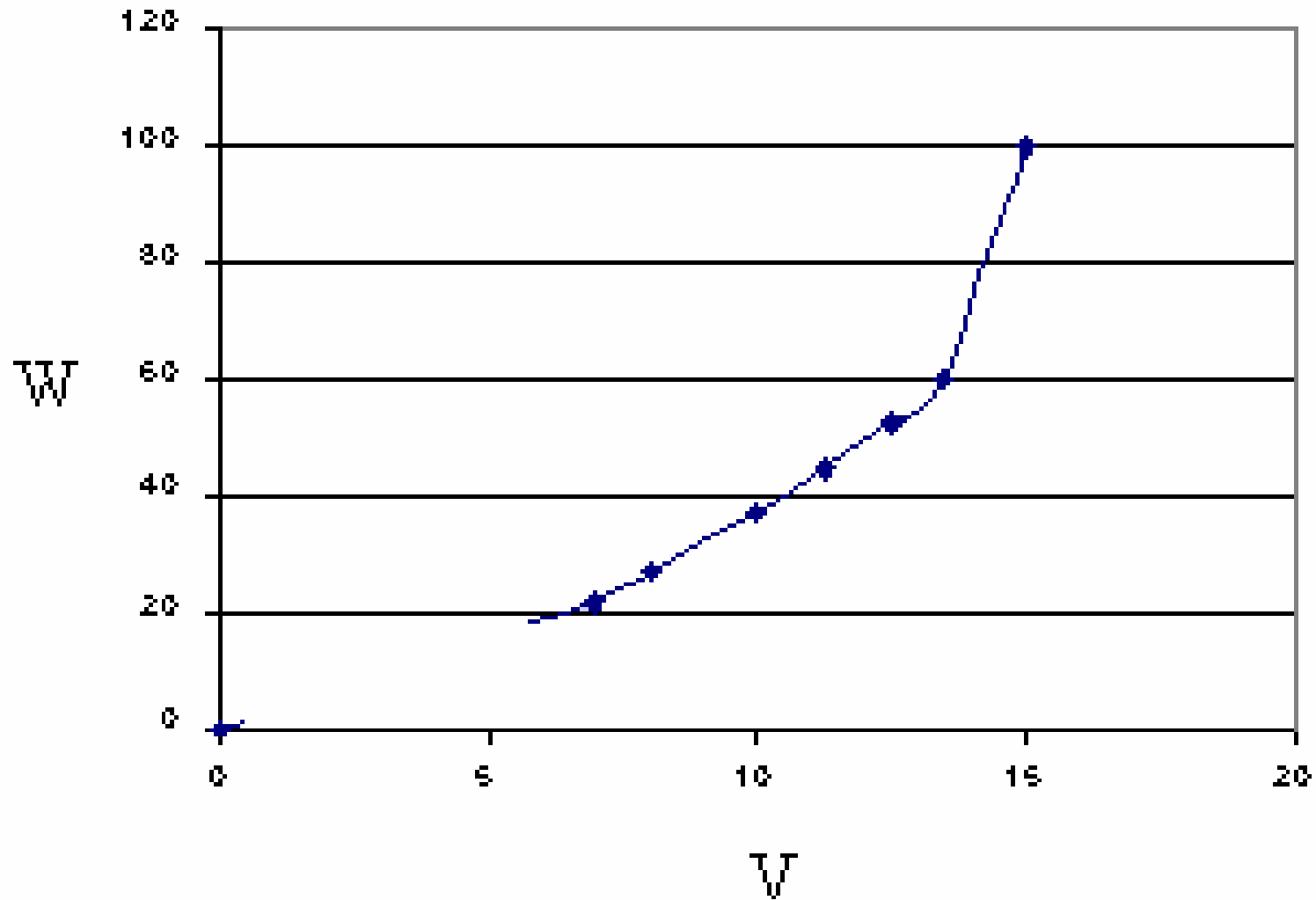
At 7 m/s

| Rotor speed (RPM) | Electrical load resistance (ohm) | Generator Power output (W) | Turbine power coefficient (p.u) | Generator efficiency (%) | WEG efficiency (%) |
|-------------------|----------------------------------|----------------------------|---------------------------------|--------------------------|--------------------|
| 422 | 0.15 | 7.0 | 0.098 | 45.0 | 3.5 |
| 443 | 0.23 | 10.0 | 0.114 | 57.0 | 5.3 |
| 461 | 0.33 | 12.0 | 0.128 | 63.0 | 6.5 |
| 474 | 0.50 | 18.0 | 0.169 | 72.0 | 9.7 |
| 515 | 1.00 | 20.0 | 0.180 | 76.0 | 11.0 |
| 534 | 1.37 | 22.0 | 0.195 | 76.0 | 12.0 |
| 559 | 3.00 | 19.0 | 0.166 | 76.0 | 10.1 |
| 623 | 6.66 | 15.0 | 0.141 | 72.0 | 8.1 |

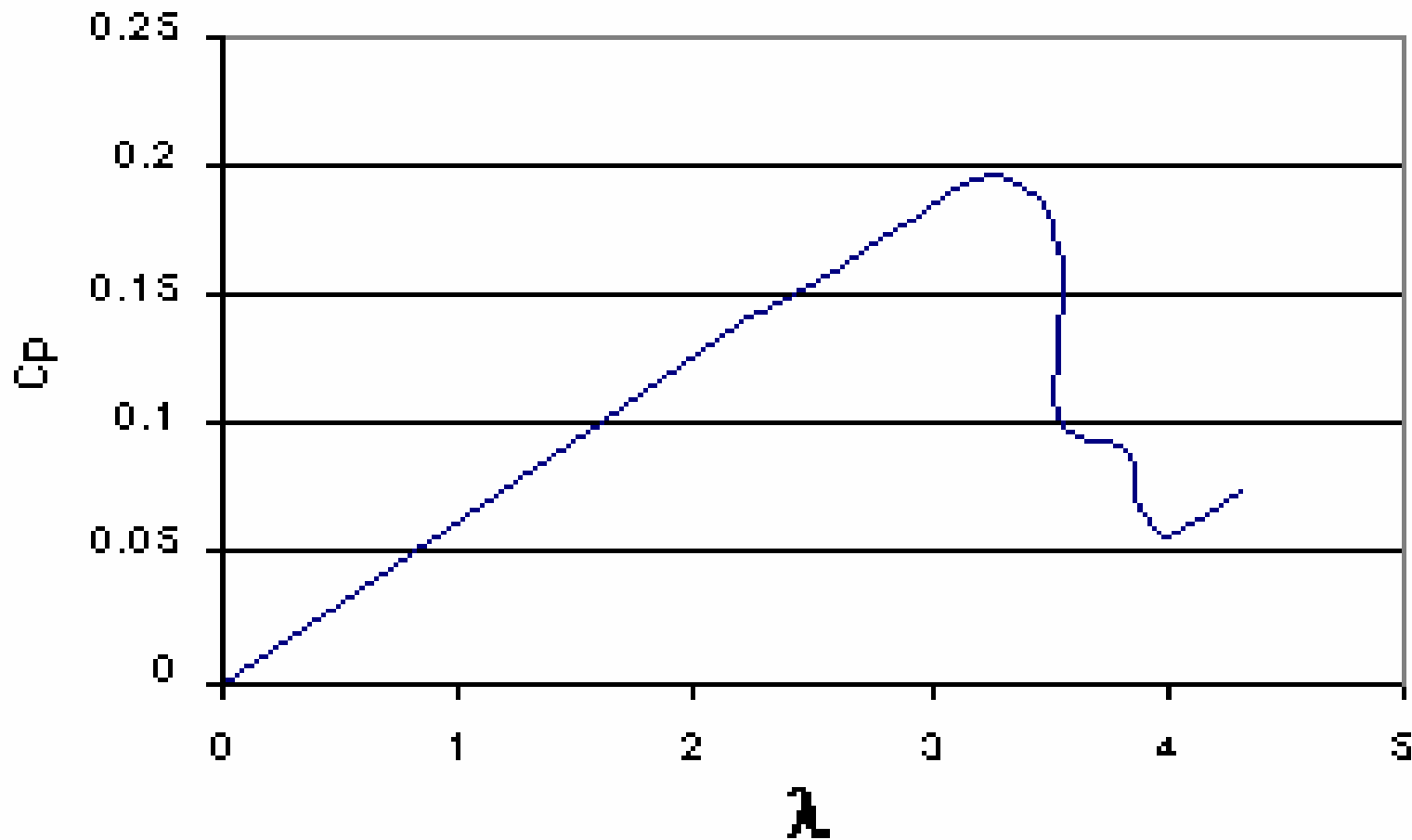
At 15 m/s

| Rotor speed (RPM) | Electrical load resistance (ohm) | Generator power output (W) | Turbine power coefficient (p.u.) | Generator efficiency (%) | WEG efficiency (%) |
|-------------------|----------------------------------|----------------------------|----------------------------------|--------------------------|--------------------|
| 1335 | 0.16 | 38.0 | 0.037 | 69.0 | 2.1 |
| 1368 | 0.25 | 49.0 | 0.044 | 76.0 | 2.7 |
| 1382 | 0.38 | 65.0 | 0.054 | 82.0 | 3.6 |
| 1399 | 0.65 | 86.0 | 0.068 | 87.0 | 4.7 |
| 1421 | 0.80 | 89.0 | 0.069 | 88.0 | 4.9 |
| 1443 | 1.05 | 95.0 | 0.072 | 89.0 | 5.2 |
| 1554 | 1.10 | 100 | 0.075 | 90.0 | 5.5 |
| 1571 | 1.60 | 90.0 | 0.068 | 90.0 | 4.9 |
| 1588 | 2.00 | 85.0 | 0.064 | 91.0 | 4.6 |
| 1604 | 2.90 | 73.0 | 0.055 | 89.0 | 4.0 |
| 1617 | 4.42 | 54.0 | 0.042 | 87.0 | 3.0 |
| 1634 | 5.33 | 48.0 | 0.038 | 86.0 | 2.6 |

Power curve of WEG



Turbine characteristics



Economic Feasibility study

Cost of construction= Rs.8000

Equipment life assumed= 15 years

Interest rate = 12 %

Capital Recovery factor (CRF) calculated from
life and interest rate

Levelised cost= capital cost * CRF

Generation cost = Levelised cost/(energy
generated per annum)

Economic feasibility study(contd.,)

| Weibull scale parameter, c (m/s) | Weibull shape parameter, k | Estimated energy per annum (kWh) | Levelised Generation cost (Rs/kWh) |
|----------------------------------|----------------------------|----------------------------------|------------------------------------|
| 5 | 1.5 | 64.04 | 18.3 |
| | 2.5 | 31.72 | 37.0 |
| | 3.0 | 22.51 | 52.1 |
| 7 | 1.5 | 125.14 | 9.4 |
| | 2.5 | 118.27 | 9.9 |
| | 3 | 113.27 | 10.4 |
| 9 | 1.5 | 161.18 | 7.3 |
| | 2.5 | 208.85 | 5.6 |
| | 3 | 216.53 | 5.4 |

Conclusion

Optimum output can be availed by appropriately choosing the load

WEG efficiency can be improved by

- modifying the blade profile
- attaining perfection in turbine construction
- using better gear arrangement

Conclusion (contd.,)

- Cut-in speed can be reduced by commercial standards
- Performance of vertical axis wind turbine (VAWT) inferior to that of horizontal axis counterpart (HAWT)
- But cost of development of VAWT is low
- So a better choice for micro wind power systems



Queries