TECHNICAL NOTE

BENEFIT OF THE OPTISTROKE TECHNOLOGY

Our target is to be competitive both price and efficiency. Our price will be below same size wind turbine price as mentioned on cost estimation document. On the other hand, efficiency of our technology is more and more competitive than prices.

Our claim is :
"Yelkapan can pump **4 times more** water than same size windpumps during a year period."

according to our calculations. We will try to measure it on test station. Our expectation is "it will be at least 3 times more". Please, find our calculation details below which the claim based on.

5.2 Rotor Power Characteristics 101

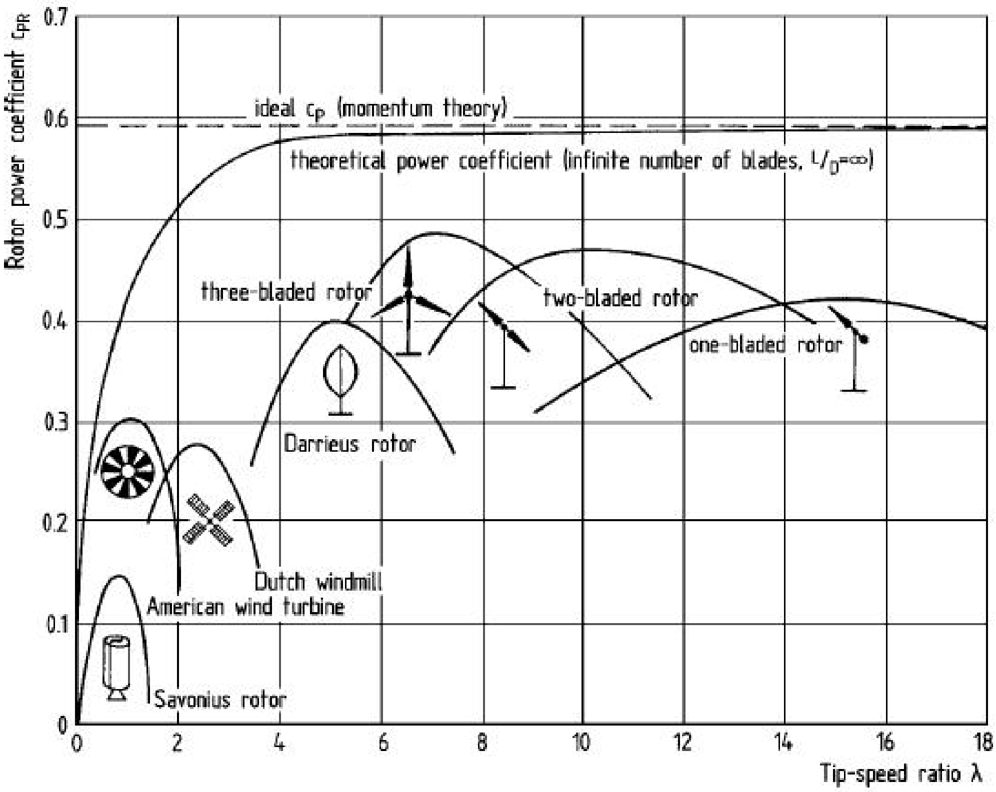

Figure 5.10. Power coefficients of wind rotors of different designs [2]

Figure 1 From the book of Erich Hau named "Wind Turbines")

This is the efficiency of the rotor only. System efficiency also includes mechanical and electrical efficiencies. In the literature (Figure 3), the rotor efficiency is approximately 40%. Sum of both mechanical and electrical efficiencies is 80%. So **the system efficiency is 32%** for commerical VAWTs. *(0,4 x 0,8 = 0,32)*

Efficiency Assumptions of ENA Wind-Pump

We assumed that the rotor aerodynamic efficiency as **35%**. We also assumed the mechanical efficiency of both drive train and pump as **60%**. So the expected system efficiency of ENA wind-pump is **21%**. The system efficieny can be defined by the following equation:

System Efficiency = (potential energy of pumped water) / (kinetic energy of blowing wind)

<u>The Hidden Problem</u> : System Efficiency Vs Wind Speed

The challenge of the wind-pump applications is <u>to keep the system efficiency at top level for different wind speeds</u>. The modern MW size wind turbines can do it by using “variable speed generator technology”. Our “variable stroke pump technology” does same job at wind-pumps.

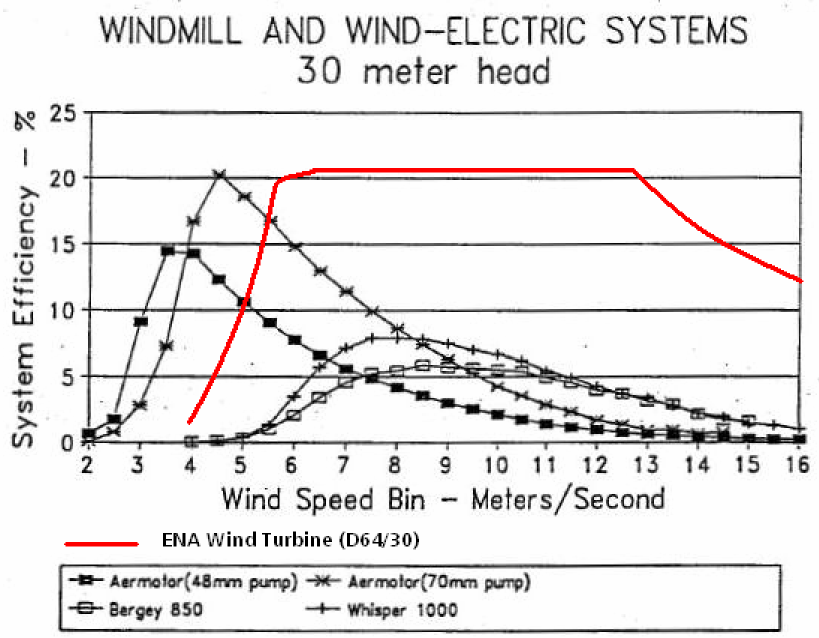

Figure 2. System efficiency at a 30 meter head for windmill and wind-electric

Figure 2 From the reference article Ref-1

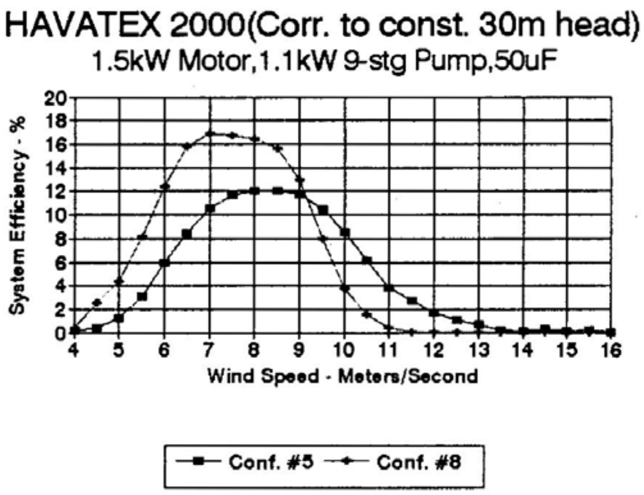

Figure 8. Effect of Pitch Angle on System Efficiency of Two Configurations Tested on Havatex 2000.

Figure 3 From the reference article Ref-2

CONCLUSIONS

By using advanced airfoils and a permanent magnet alternator with rare earth magnets, the system efficiency of a wind-electric system can be increased to 17% (the highest system efficiency ever measured at the USDA laboratory in Bushland since testing began twelve years ago). The cut-in wind

Figure 4 The conclusion text above was cut from the article Ref-2

The system efficiency problem is related with insufficient energy matching of wind rotor and water pump for different wind speeds.

Reasons for insufficient energy matching at multi-bladed windmills

Multi-bladed windmills are mechanical devices with piston pump. The piston pump is fixed stroke. So, the energy demand of piston pump is proportional with pump speed only. On the other hand, the energy supply of wind rotor is proportional with cubic of wind speed. Because of that, wind rotor runs at overspeed and aerodynamic efficiency loss occurs. As a result, wind speed changing effects directly "the system efficiency".

Reasons for insufficient energy matching at wind-electric water pumping systems

Wind-electric water pumping systems have submersible pumps. Efficiency of that kind of pumps changes according to speed. (see performance chart of standard submersible pump) Flow rate (means energy demand) is proportional with pump speed. If the wind blows below the rated wind speed, energy supply of the wind turbine decrease so the pump speed decrease. As a result, wind speed changing effects directly "the system efficiency".

Benefits of Variable Stroke Technology

OptiStroke Control Technology is the best solution for insufficient energy matching problem of wind rotor and water pump. OptiStroke system decides best matching conditions between energy demand and energy supply. By the way, the wind rotor runs at optimum speed and maximum efficiency. At the same time, the piston pump runs at optimum stroke. As a result, the system efficiency can be maximized. The result can be seen on the Figure 2 with the red line.

CONCLUSION

According to test results of reference articles, it is possible to calculate annual pumping capacities of tested windpumps with same size rotor and same pumping head. By the way, the results can be compared each aother. The calculations based on the following formula:

$$Q = \sum_{i=1}^{13} 0,2248 F \eta \frac{AV_i^3}{H}$$

where Q is annual pumping volume in m^3, F is annual wind speed frequency (according to Weibull distribution), η is system efficiency (read from charts of articles), A is rotor swept area in m^2 (64 m^2 for all), H is pumping head in m (100 m for all) and V is wind speed in m/s.

Type of windpump	Annual pumping volume [m^3]
Yelkapan D64/30	121 592
Whisper 1000	28 139
Aermotor	26 537
Havatex Config-5	28 032
Havatex Config-8	28 239

CALCULATION TABLE

η System efficiency (read from the charts)
Qi Annual pumping volume for specific wind speed

Weibull parameters for Annual Frequency distribution are k=1,69 and C=7

Wind Speed	Annual Freq.	Yelkapan		Whisper 1000		Aermotor		Havatex Config-5		Havatex Config-8	
[m/s]	[hours]	η		η	Qi	η	Qi	η	Qi	η	Qi
4	975	0,21	1885	0	0	0,17	1526	0		0	
5	952	0,21	3595	0	0	0,19	3252	0,02	342	0,04	685
6	880	0,21	5742	0,04	1094	0,15	4102	0,06	1641	0,12	3281
7	778	0,21	8064	0,08	3072	0,12	4608	0,1	3840	0,17	6528
8	662	0,21	10247	0,09	4391	0,08	3904	0,12	5855	0,16	7807
9	545	0,21	12008	0,08	4575	0,06	3431	0,12	6862	0,13	7434
10	435	0,21	13150	0,07	4383	0,04	2505	0,09	5636	0,04	2505
11	338	0,21	13582	0,05	3234	0,03	1940	0,04	2587	0	0
12	255	0,21	13328	0,04	2539	0,02	1269	0,02	1269	0	0
13	188	0,21	12492	0,035	2082	0	0	0	0	0	0
14	135	0,19	10071	0,02	1070	0	0	0	0	0	0
15	95	0,15	7087	0,02	926	0	0	0	0	0	0
16	66	0,13	4879	0,02	774	0	0	0	0	0	0
17	44	0,11	3289	0	0	0	0	0	0	0	0
18	29	0,09	2172	0	0	0	0	0	0	0	0
	Total		**121592**		**28139**		**26537**		**28032**		**28239**

It is also interesting that the modern wind-electric wind pumps have same performance with traditional mechanical windmills (like Aermotor).

Reference Articles:

1) Brian Vick and Nolan Clark, "Performance and economic comparison of a mechanical windmill to a wind-electric water pumping system", 1997, USDA Agricultural Research Service, ASAE Meeting Presentation, Paper No 974001
http://www.cprl.ars.usda.gov/REMM%20Pubs/1997%20Performance%20and%20Economic%20Comparison%20of%20a%20Mechanical%20Windmill%20to%20a%20Wind-Electric%20Water%20Pumping%20System.pdf
2) Brian Vick and Nolan Clark, "Testing of a 2 kW Wind-Electric System for Water Pumping", 2000, USDA Agricultural Research Service, AWEA Conference Proceedings
http://www.cprl.ars.usda.gov/REMM%20Pubs/2000%20Testing%20of%20a%202-Kilowatt%20Wind-Electric%20System%20for%20Water%20Pumping.pdf