BLACK SEA METEOROLOGICAL FACTORS ANALYSIS FOR IMPLEMENTING RENEWABLE ENERGY SOURCES INTO NAVAL POWER SYSTEMS

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Abstract: *The issue paper is to present renewable energy sources, insisting mainly on wind energy. This source is analyzed in the context of Romania in particular and the EU in general. A turbine with horizontal axis is usually coupled with vessel power systems. Wind energy knows an increased growth rate. At the end of the paper are presented possible structure of coupled a wind to power systems.*
Key-words: *renewable energy, wind energy, wind turbine, vessel energy system.*

1. INTRODUCTION

In the first part of these papers it’s presented a wind turbine with power P = 5KW, mounted on the Romanian Black Sea coast. The second part comprises wind speed records for a period of three months. Active power system (wind turbine + synchronous generator) was measured experimentally and presented its evolution over time.

They determined the mechanical properties of various wind turbine and wind speeds were checked with the mathematical model of naval wind turbine. In the second papers of experimental verifications was performed power dependence of the maximum wind speed cube.

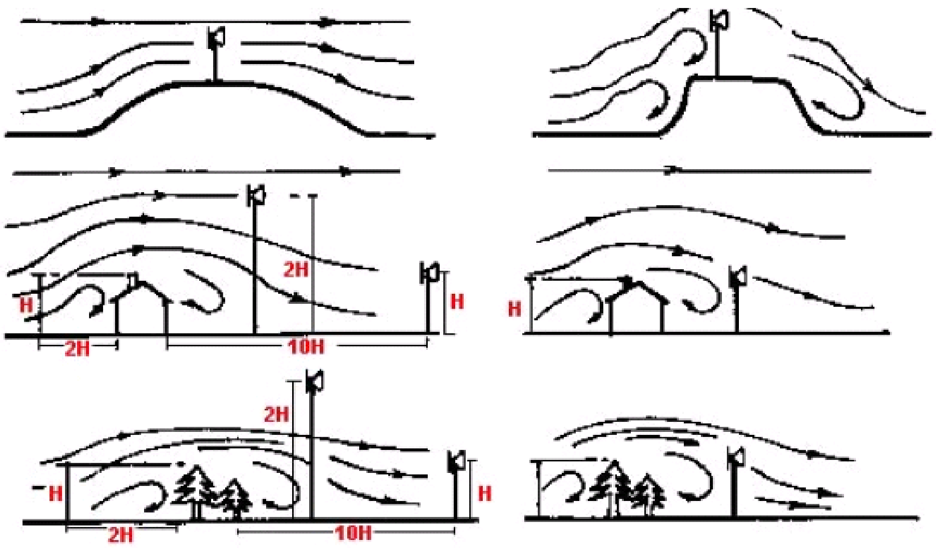
In the final papers presents the behavior Diesel Generator by recording the speed and voltage while the generator set with a Proportional-type regulator and the conclusions of the analysis of experimental results.

2. THE SPEED OF WIND IN THE AREA OF THE BLACK SEA COASTLINE

The recordings were made in the area of the Black Sea coastline in August, September and October 2010, where a field of wind power plants was mounted by the Black Sea area.

Knowing the details about the annual average wind speed from the weather observer located in the area and doing measurements with the equipment, we could estimate, with an acceptable error, the speed of wind in the August-September-October 2011 period.

Because of the swirl currents created by obstacles, the wind turbine was placed in a position that could not break the rules from the 4. figure:



good wrong

Figure 4. The mounting of turbines (well/wrong)

So the following variations of wind’s speed were obtained during August – September – October 2011:

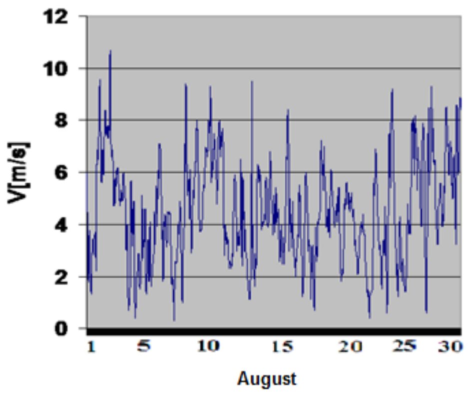


Figure 5. The speed of wind in August 2011

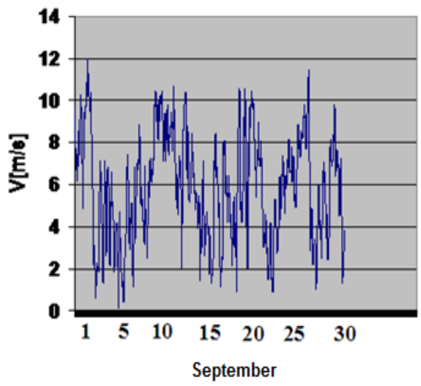


Figure 6. The speed of wind in September 2011

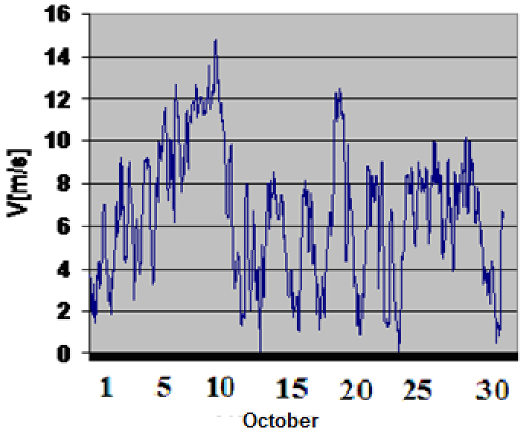


Figure 7. The speed of wind in October 2011

3. EXPERIMENTAL VERIFICATIONS OF THE MAXIMUM POWER DEPENDENCE OF WIND SPEED CUBE

The maximum power developed by a wind turbine depends on the speed cube:

$$P_{TV} = K_{TV} \bullet V^3$$

There were differences in estimating the maximum power of the wind turbine.

It also notes that on quick changes of wind speed over time, the operating point is far from the point of maximum power, and, for example, from V = 3.5 [m/s] to V = 2.2 [m/s], the load changes from 2.36 to 0.04. The use of small low inertia turbines can bring the operation closer to the point of maximum power.

4. THE DETERMINATION OF TV’S MECHANICAL CHARACTERISTICS

From experimental data: the P active power developed by the generator and rotational speed n at TV shaft, the torque of turbine is determined. The experimental verifications were made at a wind speed value: V=4 (m/s) and V=5 (m/s) for ω angular speeds of TV in the area ω=(2÷10)(rad/s).

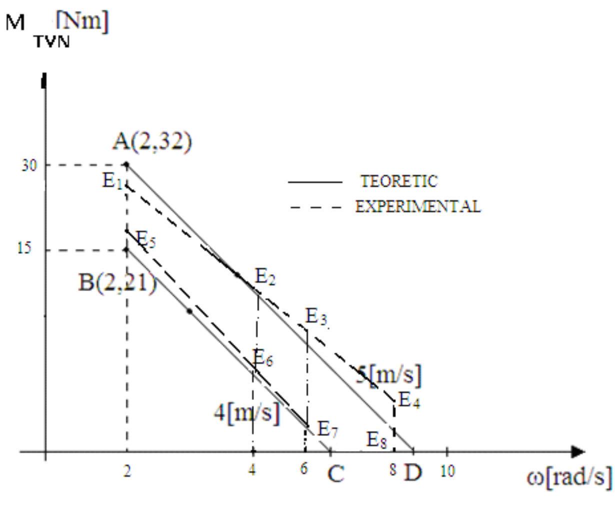


Figure 8. The mechanical characteristics of wind turbine

Knowing the power P which wind turbine is working at and rotational speed n, the values of torque were calculated in points: E1, E2, E3, E4 for the speed V=5 (m/s) and E5, E6, E7, E8 for V=4 (m/s).

For the calculation of torque was used:

$$M_{TV} = P \,/\, (2\pi n \,/\, 60)$$

where:

-p is the power measured at generator and corrected with the value of system efficiency (TV+GS);

-n is the rotational speed at wind turbine shaft;

At wind speed V=4 (m/s) the mechanical characteristic of wind turbine is given by the equation:

$$M_{TV-4} = -4.2\ \omega + 29.4$$

which approximates the mechanical experimental characteristic with an error below 4 %.

At wind speed of V=5 (m/s) the mechanical characteristic of wind turbine is given by the equation:

$$M_{TV-5} = -4.5714\ \omega + 41.143$$

This approximates the mechanical experimental characteristic with an error below 3 %.

The points of maximum power are:

-P1 for V=4(m/s);

-P2 for V=5(m/s).

and is characterized by the following values of power:

P1=51.45[W]-calculated; P1exp=52.1[W]-measured;

P2=92.573[W]calculated; P2exp=91.3[W]measured.

The differences between the theoretical results and the ones measured at those two wind speeds and taking in consideration the mechanical power captured by the wind turbine, are:

ε_1=ΔP/P1=1.25% for V=4(m/s);

ε_2= ΔP/P2=1.39% for V=5(m/s).

5. THE EXPERIMENTAL DETERMINATION OF THE OPTIMAL CHARGE RESISTANCE

As mentioned, in the locations of the coastline, wind turbines are used for charging electric batteries and therefore, as generators were used direct current generators with permanent magnets which have the great advantage for not being necessary the redressing of alternative current and so the conversion system is much simpler.

Direct current generators with permanent magnets excitation debit directly on the electric battery symbolized in the figure below by R charge.

The optimal operation of subsystem (wind turbine + permanent magnet generator + electrical acumulators) was done experimentally by tests at various charge resistances connected to the terminals of generator, as shown in figure 9.

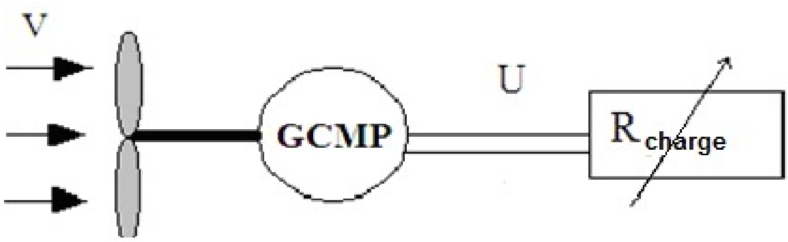


Figure 9. Wind system with resistive charge

By direct measurement of power at different values of R and V, the dependence of charge resistance from the speed of wind is obtained, while the power obtained from the turbine being maximal. Maximal power was obtained through small changes of charge resistance around the values obtained from the calculation.

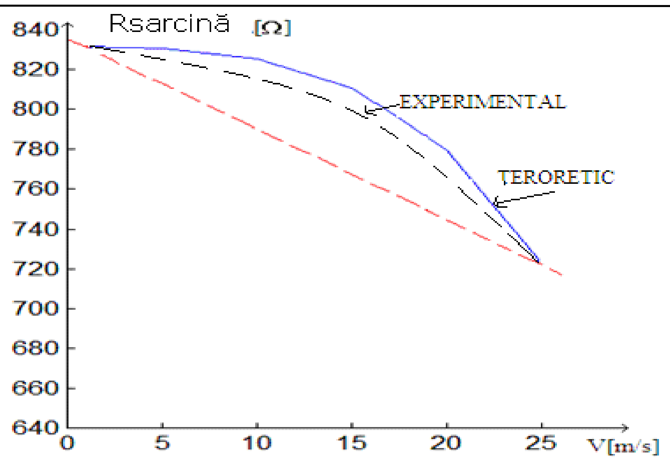


Figure 10. The dependence on charge resistance

The energy measured after a time T=5555[s] is compared with the one calculated below:

a) For $R = 831[\Omega]$: $W_{exp} = 1.1654 \times 10^6[J]$; $W_{teoretică} = 1.156 \times 10^6[J]$;,

b) For $R = 931[\Omega]$: $W_{exp} = 1.1334 \times 10^6[J]$; $W_{teoretica} = 1.124 \times 10^6[J]$; ,

c) For $R = 531[\Omega]$: $W_{exp} = 1.2235 \times 10^6[J]$; $W_{teoretică} = 1.217 \times 10^6[J]$,

d) For $R = 231[\Omega]$: $W_{exp} = 1.0536 \times 10^6[J]$; $W_{teoretică} = 1.052 \times 10^6[J]$,

e) For $R = 31[\Omega]$: $W_{exp} = 4.3881 \times 10^5[J]$; $W_{teoretică} = 4.351 \times 10^5[J]$,

f) For $R = 1531\Omega$: $W_{exp} = 9.3638 \times 10^5[J]$; $W_{teoretică} = 9.359 \times 10^5[J]$.

The differences between the theoretical results and the experimental ones are below 1.5 % which confirms the validity of mathematical models of the naval wind turbine.

6. THE DIESEL-GENERATOR SYSTEM BEHAVIOR

At a Diesel-Generator group on a ship from the endowment of the merchant maritime fleet experimental verifications to the system’s behavior in transient regime were made.

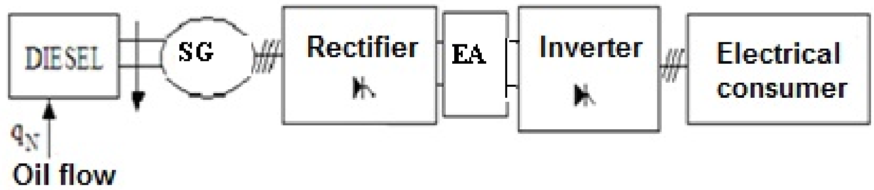
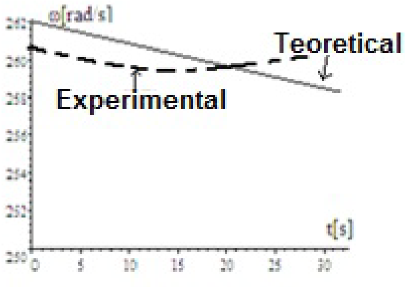


Figure 11. Diesel-Generator Group

From the simulations, result the time variation of angular mechanical speed – ω – and the – U – electric tension at the generator by use of a proportional-type regulator.

The experimental results confirm these variations as shown in figures 12. and 13.



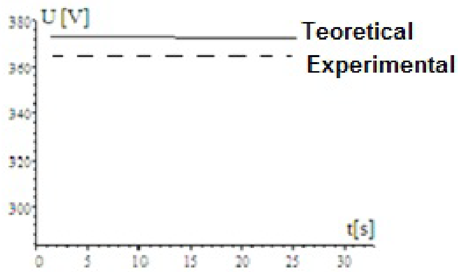


Figure 12. The time variation of ω **Figure 13. The time variation of electric tension**

The differences between theoretical results and the experimental ones are below 3% which confirms the validity of mathematical models of Diesel Engine and Generator.

7. CONCLUSIONS

The recordings made in the area of the Romanian Black Sea coastline have demonstrated the fact that the wind potential in this area is important and so it’s exploitation is economically viable both on land and sea

From the experimental data taken from an operational wind turbine in 2011 in Dobrogea area, the accuracy of equations which models the mechanical characteristics of wind turbine, characteristics which were used throughout the article. In the analysis of powers, the torques were calculated and compared with those obtained from the calculation. The differences were less than 2% in estimating the maximum powers of wind turbine operating.

The experimental verifications on operating in the points of maximum power have revealed the fact that at low wind speeds and at fast and significant changes of wind speed, the wind system does not always work in the points of maximum power, because of the high mechanical inertia of the system (wind turbine + synchronous generator). These aspects have been widely analyzed during the thesis, where you can see the big influence of the equivalent moment of inertia of the electric turbine-generator system. Important roles in ensuring the stability in operation have regulators whose award is made after careful analysis of the system behavior.

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