DATA ACQUISITION AND NUMERICAL MODELLING FOR A WIND TURBINE POWER-PLANT

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Abstract - The paper is structured into five parts, taking into account the main steps followed into a wind farm implementation. In the first part, some general remarks are presented. In second part are mentioned the adopted wind towers for monitoring environmental data acquisitions, followed into the third part of a selection of different types and dimensions of wind turbines, selected for modelling, in conformity of desirable amount of electric power to be produced by the wind farm. In forth part, are presented main steps followed into numerical modelling of the wind farm, its structure, conditions to be considered in conformity of local terrain, estimation of efficiency and of the number of functioning hours. Finally, into the fifth part some conclusions are presented, followed by few references

Keywords: data acquisition, numerical modelling, wind farm structure, efficiency estimation.

1. INTRODUCTION

The renewable resources represent an energetic important potential and offers unlimited possibilities of utilisation on local and national system. In establishing of future wind farm is should be taking into account three hypotheses: accessibility, disposability and acceptability.

An important advantage of wind power farms represents the small surface affected, due to the fact that, at local area we may maintain all agricultural, social and economic activities. In the last ten years, in Europe, utilisation of wind energy registers a permanent development (annual rate increasing being around 30%); nowadays due to nuclear registered accidents it became more and more actually. All industrial involved partners recognise that, in conformity with the present development of wind power systems, is possible that they will assure into next 20 years around 15% of total produced energy.

EWEA, European Wind Energy Association mentioned that in present “energy produced from wind resource is now an efficient and economic solution”.

The actual performance of wind turbines extends the domain of wind scale utilisation, from higher then 8m/s five years ago to 4m/s actually. That represents an increasing with more then 60% of available resources.

In Hungary, Vestas Company implement 12 wind turbines V90 of 2 MW each, in Region Bony, 80 km west from Budapest, starting with the forth trimester of 2009. The investment is realised by Euro System of Green Energy who already has installed another 11 functioning wind turbines. In Bulgaria 4 big wind-farms are already implemented, starting 2010.

Theoretically, Romania may produce around 14000 MW only from wind resources, representing more then four times than Bulgaria. In fact, the produced energy from wind resources in Bulgaria exceeds 37 times the present production from our country.

In Romania are scheduled to be finalized some projects into near future, by GE Energy, with around 100 wind turbines in Cogealac, area Constanta, representing one of the biggest projects developed by Czech part, with around 600 MW, an investment of 1.1 billion Euros.

The European Union mentioned, as one of the principal targets to Romania, to assure an increase of produced energy from renewable resources, including wind energy at 20% from total produced energy until 2020. During realisation of some projects some of the developed countries will subvention partially, the investments to countries less developed. The European authorities did not establish till now the contribution of each state to this project, but Andris Piebals, the European Commissar for Energy presented his opinion that it should be implemented a project which will allows to the governments of the UE new members to access a credit dedicated to this domain (Romania included).

The paper presents the main steps followed in modelling a wind farm, having around 15MW installed, starting to data acquisition, until estimation of park efficiency. The selected area for implementation is based on previous results, and some environmental acquisition, into Siret basin and of course, taking into account the wind map from the Monitoring Report concerning wind potential. To perform the calculations were selected also long time data acquisition, to create a correlation in estimation of the energy production. With these data was realised an estimation of energy production for the wind turbines: General Electric GE2.5xl, GE2.75 and Vestas V90, V100, V112.

All obtained and presented results during this paper are in conformity with internal normative and actual ISO standards.

2. ENVIRONMENTAL DATA ACQUISITION

To perform the numerical modelling, data acquisitions was accomplished during more then one year into selected area, with a wind tower having 60m high, fully equipped. The results was tested and validated with long-term correlated data.

In present context in Romania, referring at extension of utilisation of renewable resources, held a constant campaign for monitoring environmental data, in order to locate the economically favourable zones. Fig.1 presents the distribution of wind intensity, with velocity higher then 4 m/s; in legend are mentioned the registered number of hours. Actually in Romania, less of 1% from total produced energy is from wind resources.

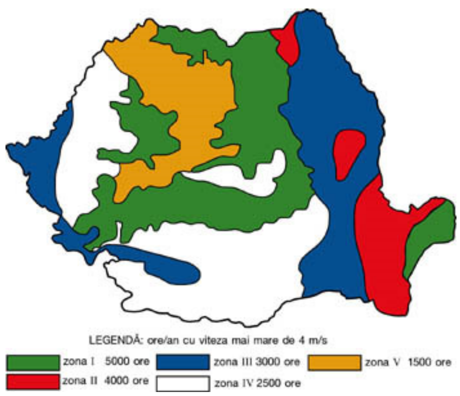

Fig. 1. Areas with wind velocity higher then 4m/s

Considering a PHARE study, the total wind potential of Romania is around 14000 MW installed power, respectively 23000 GWh/year. Considering only technically and economically potential remains around 2500 MW; then the total produced electric energy will be approximately 6000 GWh/year, representing 11% from the total produced energy from our country.

It must be mentioned that by realizing wind power systems new working places will be realized, will be reduced the consumption of conventional resources and will be reduced the emission of CO_2.

The environmental data acquisitions were registered during more then one year, into the selected area, Fig.2, one of the red areas presented into Fig.1. In this area, another argument of developing a wind farm is the relatively constant direction of wind blowing. To encourage the production of wind energy not only the price of sold energy is important but also the obtained Green Certificates, possible to be negotiate into international market. Each MW produced by wind energy will receive two Green Certificates.

Fig. 2. Selected area for wind farm

The power plant will be equipped with wind turbines having the hub at approximately 100m high. The environmental data register with two turn towers having 60 m, fully equipped: anemometers and wind vanes placed at 60m, 50m and 40m from ground, fig.3, sensors for temperature, humidity and temperature at 10m high. In top of the tower is present a red system lightening during night. A data-logger and a solar panel are also part of the tower, fig.4.

Fig.3 presents images with tower system of measurements, with its anchors, on 4 directions at 7 different levels.

Fig. 3. Wind tower fully equipped

Fig.4-a is with images with data-logger Nomad2, for registration and sending of collected data and with the solar panel for power alimentation. Fig.4-b shows an image with data-logger during realization of connections of sensors. At this type of data-logger may connect until 12 sensor and solar panel. After the implementation of towers, at each 3 months a specialised team assure maintenance of full equipments.

Fig. 4. Data-logger and solar panel

The recuperation rate for the entire registered period is 99.12% and for the period taken into analyse was 99.87%. The Data-logger registers at each second for wind speed and direction. Those values mediate at 10', together with standard deviation, air temperature, pressure, humidity into binary files. The binary files convert into ASCII text files with specialized acquisition soft. Fig.5 presents time duration curve, for wind velocity at each anemometer, placed at 60m, 50m and 40m.

With mediated values at 10' is elaborated the wind rose, for each anemometer, fig.6. Some calculation referring at influence of the tower on wind distributions, influence to one anemometer to each other, vertical distribution of wind direction, etc must be also considered.

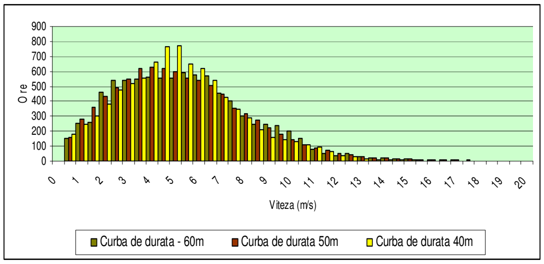

Fig. 5 Time curve for each anemometer

For each anemometer, at different time interval, is elaborate a wind rose; fig. 6 presents one of them.

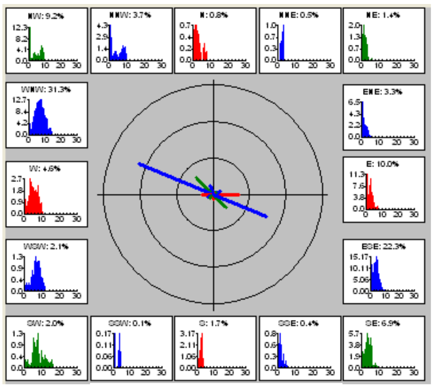

Fig.6. Wind rose for A1

Another important aspect is the frequency of appearance of wind velocities; Figs.7-9 represent the frequency for each altitude.

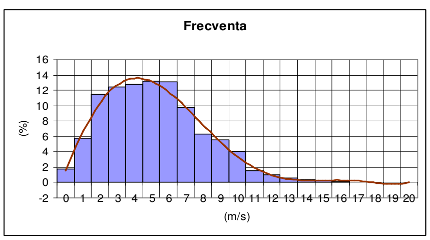

Fig.7. Frequency at 60m

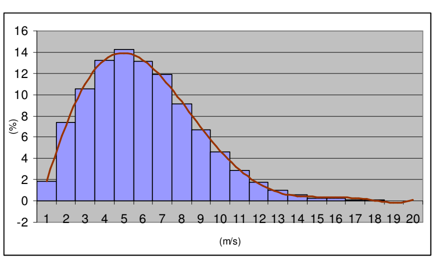

Fig.8. Frequency at 50m

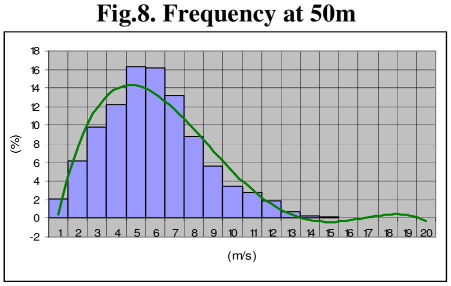

Fig.9. Frequency at 40m

A table with filtered data with maximum, minimum value registered at 10' is also realised, followed by the instant maximum value, registered at 1''. The measured data, during entire year confront and calibrate with long-term data. For the wind farm, the calculation is realised with data selected from the last 20 years. Fig.10 presents the dispersion of wind velocity: green for long-term data and blue for measured data.

The selected points of long-term data acquisition were selected as to surround the tower of measurement and the second aspect was to impose that the distance between tower and data point is smaller then 20km.

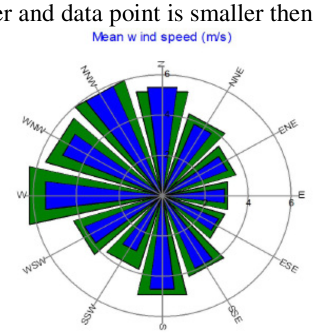

Fig.10. Data comparison: long term and actual acquisition

3. WIND TURBINE TESTED FOR PARK MODELLING

For modelling this wind farm were selected five types of wind turbines, all of them having almost the same power: VESTAS V100-1.8 MW, VESTAS V90-2MW, GE 2.5xl, GE 2.75 MW and VESTAS V112 - 3MW. The main characteristics are presented into Table 1, and images of them into Fig.11.

Table 1. Main characteristics of selected turbines

Type	Rotor Diam	Hub high	Installed Power	IEC
-	m	M	KW	-
V100	100	105	1800	III
V90	90	105	2000	I+III
GE2.5x	100	100	2500	II+III
GE2.75	103	103	2750	II+III
V112	112	119	3000	II+III

Fig. 11. Images of selected turbines

Wind turbines are selected based on:

- Main wind velocity at hub high;

- Axis of the rotor should be at high enough level as to minimise the influence of roughness of terrain;
- Competitive price on international market

4. MODELLING OF THE WIND FARM

In Fig.12, into selected area for implementation, are placed the wind turbines; the map is represented at scale. In realisation of wind farm, the main criteria were to respect the distance between turbines as to minimise the reciprocal influence and to assure an optimum circulation of wind to all turbines. Fig.13 shows the imposed restricted area, in conformity with international normative. Fig.14 presents a map of roughness of terrain, elaborated with a dedicated soft. In estimation of the efficiency of each turbine, conform internal and international normative, for each equipment, for each altitude were calculated the incertitude in functioning. The factor of influence considered for each turbine is introduced into final calculations into establishing the wind farm efficiency.

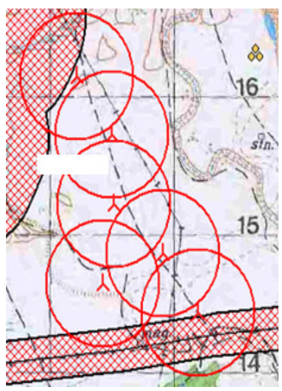

Fig.12. Wind farm model **Fig.13.Restricted area**

For a proper modelling, have been respected international normative of installation of measurement equipment, the distances and orientation of anemometers mentioned into basic guide scheme. Systematic visits into selected site are made, during all monitoring period.

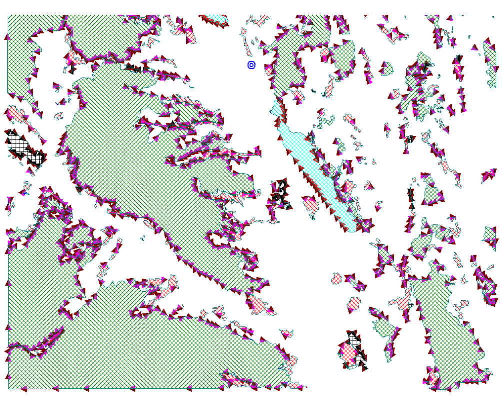

Fig.14. Map of roughness of terrain

The next step into park modelling was based on:

- Power generation curve for each wind turbine, offered by manufacturers;
- Estimation of velocity at hub high, taking into account different hypothesis on vertical distribution of wind;
- Based on measurement of humidity, pressure and temperature is realised an estimation of variation of air density during a year;
- The intensity of wind velocity is realised for each direction from the wind rose, presented into Fig.6;
- Also are considered the influence coefficients for each selected model of wind turbine.

Fig.15 and Fig.16 present the influence of wind speed-up on two main directions on wind intensity.

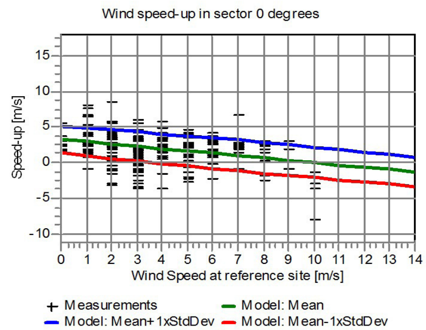

Fig.15. Wind speed-up in sector 0°

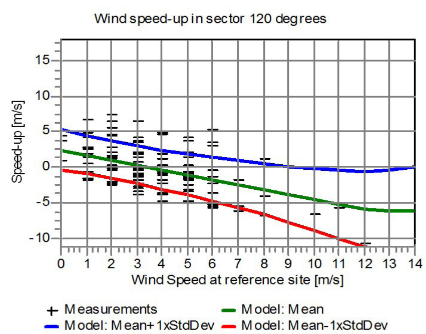

Fig.16. Wind speed-up in sector 120°

Fig.17 presents the influence of hills, roughness and obstacles on wind velocity profile.

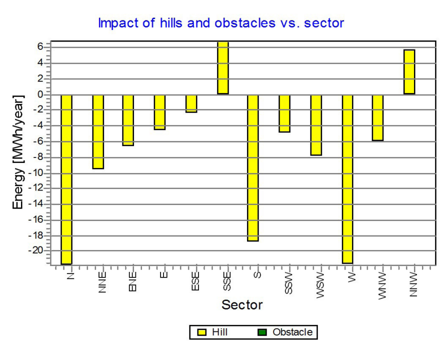

Fig.17. Influence of hills and obstacles

Life time of a wind farm is estimated as to be 30 years; due to the fact that we have only one year of complete monitoring data, it's necessary to complete and compare the data acquisition with the NCAR long term data. We selected the last 20 years. This correlation bases on wind velocity (acceleration-deceleration) and on wind directions. Some average corrections introduced into long-term values and acquisition data from the selected area, represent modifications for modelling it-self, into the matrix. Based on these calculations were established the efficiency coefficients for each turbine model from the wind farm, Tab.2.

Table 2. Efficiency for each selected turbine for modelling into wind farm

UTM	Hub high	Turbine type	Efficiency
G01	100	V90 – 2MW	98.2
G02			94.0
G03			94.3
G04			95.4
G05			93.0
G06			98.0
G01	119	V112- 3MW	97.3
G02			92.2
G03			92.3
G04			94.2
G05			91.9
G06			97.1
G01	105	V100 – 1.8 MW	98.0
G02			93.5
G03			94.5
G04			95.8
G05			93.3
G06			97.6
G01	100	GE 2.5xl	98.8
G02			96.3
G03			96.6
G04			97.5
G05			95.9
G06			98.9
G01	100	GE 2.75	98.4
G02			95.9
G03			96.4
G04			97.7
G05			95.3
G06			98.4
G01	100	V90 – 2MW	98.2
G02			94.0
G03			94.3
G04			95.4
G05			93.0
G06			98.0

Graphic from fig.18 presents the obtained results for estimated produced energy, on each direction.

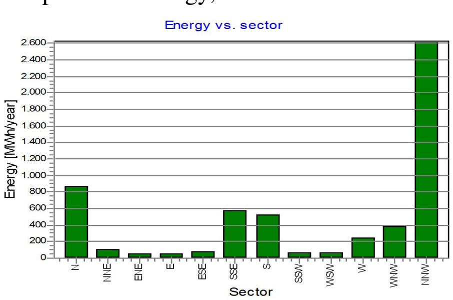

Fig.18. Estimated energy on directions

The specialised programs in modelling, for the separate wind turbine and for the entire park are considered only the optimum situations, without taking into consideration non-availability in operation. In reality, for an appropriate estimation of energy production, the next aspects should be considered:

- Power management and technical availability of wind turbine;
- Technical availability of station of transformation;
- Losses into internal network;
- Degradation and possible icing of the propeller
- Performance of power characteristic for each turbine
- Restrictions imposed for noise and shadows due vicinity of hills or buildings. Finally, a graphic like in fig.19 may be realised.

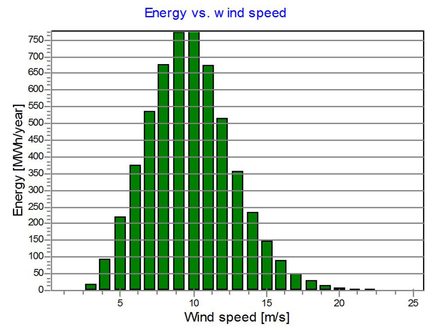

Fig.19. Estimated energy due wind velocity

For each analysed turbine type, is estimated the possible energy to be produced on each sector. With this calculation is realised the park efficiency, wind velocity distribution into the park area, turbulence, unperturbed velocity and finally the reduced velocity at hub level. Fig.20 presents a model of the obtained results, for each sector, for one of the selected wind turbine.

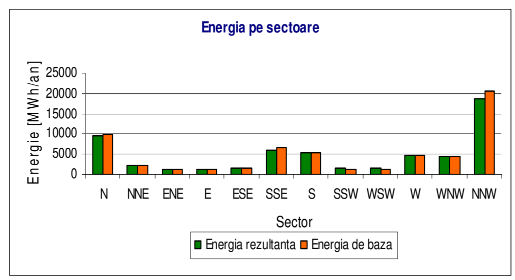

Fig.20. Estimated energy on each sector

For the same turbine, fig.21 presents wind distribution and orientation into park area.

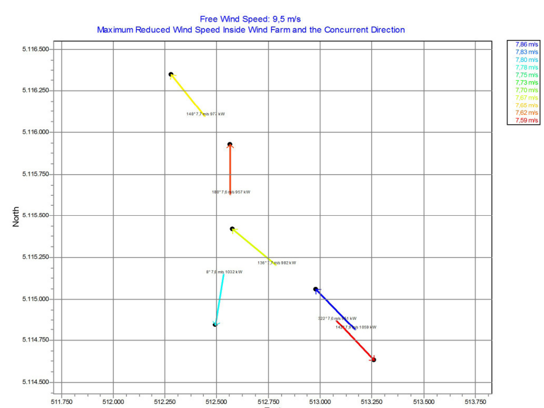

Fig. 21. Wind direction into the park

Making a comparison between each turbine, into the same conditions of exploitation is easier to establish an optimum solution. Due different dimension of hubs and propeller blade into the wind park will appear different velocities, and different orientations. Fig.21 presents the reduced velocity into the park, taking into the consideration the influence of the each turbine to others. For each wind turbine, the numerical modelling was accomplish for three values of velocities: 9.5 m/s, 14 m/s and 19.2 m/s.

Tab.3 presents for turbine V90, as an example, the estimated produced energy and in tab.4 for the selected turbines, the estimated energy produced.

Table 3. Estimated energy for V90

WTG		Annual Energy	Efficiency	Mean win speed
Type	No.	[MWh]	[%]	[m/s]
V90	1	8931.959	99.3	10.8
	2	8594.395	97.7	9.2
	3	8654.076	98.1	9.8
	4	8759.319	99.2	10.2
	5	8679.374	98.3	9.9
	6	8687.576	98.6	10.1

Table 4. Estimated produced energy

Roughness Class	1.0 – 1.8
Equipment	Nomad
Wins speed at hub height	8.4 – 8.9 m/s
Mean energy Production/year	97000 -850000 MWh/an

To establish the park efficiency for an entire year the calculations were accomplish for each month separately. Fig.22 shows the obtained valued for each month, and fig.23, presents as final the entire estimated produced energy for one year for each turbine.

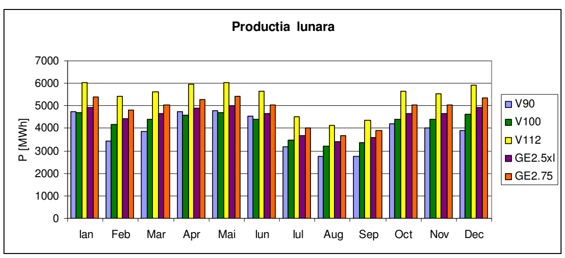

Fig.22. Produced energy during an entire year

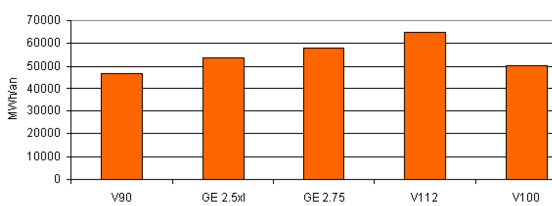

Fig. 23. Wind energy production into the park

5. CONCLUSION

The performance of a wind farm is additionally conditioned not only by the technical availability of installations but also of the any kind of losses, into the entire park, including electric one. Since these values are depending by the electric grid connections, the beneficiary must consider into the same time this aspect. The production estimations have been calculated taking into account a technical availability of 100%, based on fact that the wind turbines are new. From this value, just to obtain as real as possible, the value of the wind farm production must be reduced with different losses, first due to wind turbine utilisation and second due to wind farm structure.

The calculation was accomplished based into measured environmental data, into selected area with calibrated anemometers at different levels, 60m, 50m and 40m and also based on NCAR data obtained from international recognised stations, for long time correlation, respective last 20 years.

The average multi-annual value of wind velocity into the selected area, at level of 60m is 7.9 m/s, at 50m is 7.4 m/s and at 40m is 6.9m/s. Based on different hypothesis referring at vertical distribution of wind intensity, in conformity with soil roughness, is estimated the main wind velocity at hub high (around 100m).

Considering the obtained values of wind velocity and direction, the selected site is suited for the technical use of wind energy, at IEC III conditions.

There were analysed, completed and filtered the inconsistent data (maximum value at 1") and have been evaluated into the field the correct boom implementation. Based on the analysed documentation, the working team recommend application of a total incertitude of 5.15% into wind velocity estimation, of 5.6% into farm functioning, representing and a total of incertitude of 10.76% at energy production estimation from the mentioned location.

The numerical modelling was realised with recognised software, licensed and accepted at international level for this kind of evaluations. The team members are certificated as expert into utilisation of this software.

The final estimated energy capable to be produced with six turbines into the selected area, in conformity with terrain situation confirms the wind potential of zone.

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