First Year of Wind Parameters Measurements in Macedonia

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Abstract — In Macedonia there is no accurate knowledge of country's wind resources and it is a major barrier for any possible development of the utilization of wind power. The paper explains developments in last couple of years considering exploration of Macedonian wind resources. First of all a Wind Atlas of Macedonia was created in 2005. According the Wind Atlas the sites with the most promising wind potential were chosen. On four of this sites complete measurement stations were installed in June, 2006. The measurement campaign is lasting for 12 -15 months and this year the first results are available.

Keywords — Wind energy, wind atlas, measurement of wind parameters.

I. Introduction

In last 15-20 years the wind energy exploitations faced dramatic development world-wide. The target set by EU commission for 10% wind generation penetration in overall electricity production in European Union by the 2010 now it seems feasible, and this goal will be reached even earlier. In Macedonia few dedicated professors from Faculty of Electrical Engineering (FEE) in Skopje started to push the idea that investigation of country wind resources is something that should be done as soon as possible. In fact the first step for wind farms development is to determine accurately the wind resources and potential wind energy production of a future wind farms in selected candidate sites. Unfortunately in Macedonia there is no accurate knowledge of country's wind resources and it is a major barrier for any possible development of the utilization of wind power. The available wind speed information in Macedonia originates from the national network of meteorological stations, which - as in the rest of the world – used alone are not sufficient for accurate wind resource assessment.

This situation was inspiration to make strategic plan for investigation of wind resources and potential and possible development of wind farms in the near future. The plan is consisting of three main phases: preparation of wind atlas which is numerical modeling based on geophysical and meteorological inputs, conducting of measurement campaign on the most promising sites defined from the atlas and preparation of feasibility studies as basis for possible erection of wind farms.

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The first phase was conducted by ESM (the former Electric Power Company of Macedonia) and Wind Atlas was prepared by AWS Truewind Company from U.S.A in May and June, 2005. The second phase, now underway, is measurement campaign of wind parameters on selected sites. This phase is sponsored by Norwegian Ministry of Foreign Affairs with active participation of FEE and ELEM.

The four complete measurement stations with sensors, data loggers and musts were provided in April, 2006 and installed in June, 2006. The height of towers is 50 meters.

II. Wind Energy Atlas

The Wind Atlases are based on numerical modeling of the large-scale climatology of the atmosphere. The inputs for modeling are typically taken from global databases: the wind field could be taken from the NCEP/NCAR database, the land-use from the GLCC data base of USGS (United States Geological Survey) and the height information of the country from the SRTM30 database by NGA (National Geospatial-Intelligence Agency) and NASA. This information is validated with all other available information (e.g. maps, satellite images, etc.).

In our case the medium scale modeling has been made to resolve atmospheric phenomenon on scales down to the order of 10's of kilometers. The model enables an understanding of the overall wind resource to such an extend that informed choices can be made for setting up measuring campaigns on selected sites. This wind atlas represents the mean of winds modeled in the medium scale class simulations after adjustment to specific standard surface conditions, uniform roughness and level terrain.

The Atlas output are two main products: (1) color maps of mean wind speed and power density at various heights above ground and (2) data files containing wind speed and direction frequency distribution parameters. The maps and data can be compared with actual wind measurements, if any are available, and adjustments to the wind maps can be made.

A. Wind maps

The Atlas are consisting of maps for wind speed at four heights from the ground (40m, 60m, 80m and 100m, hard copy) together with the ArcReader software which allows user to obtain the "exact" wind speed and wind direction values at any point. The wind maps are showing that the best wind

resources in Macedonia is generally found along high mountain ridges, while lowlands and valleys are likely to have much lower average wind speeds. The predicted mean wind speed at 80m height on the ridge tops varies from 6,5m/s to 8,5m/s. Unfortunately the windiest areas are at elevations above than 2000 m, which may be expensive for wind projects.

Sites of moderate to good wind resources exist at lower elevation, however. Perhaps the most important examples are the hills on either sides of the Vardar River between Demir Kapija and Gevgelija, where the predicted mean wind speed reaches 7 – 7,5m/s at 500 -800m above see level. The river valley forms a gap in the mountain range, through which the wind flow is concentrated under some weather conditions.

The surface roughness surrounding a site also plays a big role, open fields and bodies of water experience greater wind speeds than urban or forested areas. It should be clear that the predicted wind speed at any particular location by the Atlas may depart substantially from real values due to errors on surface roughness, land cover, etc.

B. Site selection

The analysis identified 15 candidate sites for wind farms, which were selected and ranked on the base of predicted mean wind speed, wind plant size, turbine output, cost of energy, interconnection cost and other factors. A brief summary of parameters for each site is provided in Table 1. The predicted wind resource at each point on the map was combined with elevation and temperature data to estimate the net annual output of 1,5 MW turbine with a 77 m rotor diameter and 80 m hub height.

The GIS-based approach considered the factors like: the costs for new transmission lines for connection to electricity grid, the costs for new access roads, and terrains with slope greater than 20% based on SRTM digital elevation model, the gross turbine output was reduced by 12% to account planned maintenance and outages. These factors were combined with the minimum output for wind farm of 25 MW to predict the cost of energy (COE).

The amount of land area required for a 25 MW wind farm project depends on the type of terrain, direction of the wind, and other factors. In the program were assumed two extreme cases: a broad valley or plain with a multi-directional wind resources and a narrow ridge with a nearly one-directional wind resource. The program interpolated between these two extremes depending on the shape of the site.

The selected 15 candidate sites have a potential plant capacity between 25 MW and 33 MW. The cost of energy (COE) for the sites range from $0,07/kWh to $0,094/kWh, assuming a 25MW plant capacity, 15% fixed charge rate and no subsides or other incentives for wind projects. The predicted mean wind speed ranges from 6,7 m/s to 8,4 m/s. These figures are within the normal range for commercial wind projects being developed today.

An AWS Truewind engineer together with ESM engineers carried out a field inspection of selected sites between May 29 and June 3, 2005. The purpose of the trip was to assess the accuracy of the data used in the site selection, to assess the suitability of mountain ridge for installation of meteorological masts and wind turbines, to check the quality of roads, any restricted areas such as military facilities or telecommunication towers and microwave links.

After the site screening was completed and careful consideration of all obtained data by the Atlas were made, four sites were chosen for wind measurement campaign.

Site 7 - Kozuf Mountain has greatest potential for development of wind farm. It is large open grassland and the top of the ridgeline consists of gently rolling hills. The site elevation between 1300m to 1760m may produce problems during installation phase and maybe for maintenances of turbines.

Site 10 – Ranovec Mountain, Bogdanci, the ridge has 450-500 m elevation and an east-west orientation in an area where the wind is predominantly from the northwest-southeast. The vegetation on the site is grass and low shrubs and the site is located between three 110kV lines linked into triangle. Maybe this site is the most promising.

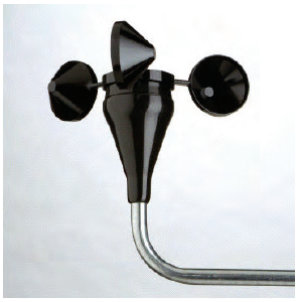
TABLE 1. The predicted parameters of 15 chosen sites from Wind Atlas

General site data				25 MW Capacity				
ID	LON	LAT	Avg Elevation (m)	SPD 80m (m/s)	PWR 80m (W/m2)	AREA (km2)	DENS (MW/km2)	MW
1	21,02	41,25	1896	8,41	700	2,1	12	25
2	20,7	41,41	2079	7,97	502	2,1	12	25
3	22,39	41,35	566	7,35	482	2,2	11,5	24,9
4	20,82	41,54	1994	7,63	482	2,1	12	25
5	20,52	41,26	2088	7,85	690	2,1	12	25
6	21,95	42,31	1159	7,53	518	2,1	12	25
7	22,3	41,25	1453	7,45	581	2,1	12	25,4
8	22,27	41,4	641	6,96	370	2,2	12	26,4
9	20,81	42	2511	8,06	640	2,1	12	25,4
10	22,56	41,23	408	7,04	502	2,2	11,4	25
11	22,46	42,13	2003	7,3	488	2,1	12	25
12	22,18	41,15	1998	7,43	666	2,2	12	25,9
13	20,72	41,8	2134	7,13	413	2,1	12	25
14	21,38	41,72	2319	7,29	566	2,3	12	27,4
15	22,45	41,78	1577	6,68	384	2,2	12	25,9

Site 16 – Sasavarlija, Stip the site was identified by ESM people. It is located around 20 kilometers to the southeast from the town of Stip on highland with several dispersed hills and a maximum elevation of 996 m. The predicted mean wind speed at 80 meters is 5,81 m/s with capacity factor of 22,44%.
Site 20 – Bogoslovec, Sveti Nikole this site was also identified by ESM people. The site is on short ridge of up to 750 m elevation. The site has moderate winds of 6,0 – 7,0 m/s at 80 m according to the wind map and is estimated to have the potential to accommodate wind farm to 10 MW

III. MEASUREMENT CAMPAIGN

The objective of measurement campaign is to measure and to analyze the wind parameters on four locations with promising potential of wind energy. The final goal is to obtain valid results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms. This is the next phase, after the preparation of Wind Atlas, in overall scientific determination of regions and locations with promising wind energy potential. This initiative is perfectly fitted with governmental strategy for developing of renewable resources. The possible development of wind power plants in the near future will also have positive implication on the local economy.
The project is running by FEE (Faculty of Electrical Engineering) – Skopje together with ELEM (Electric Power Plants of Macedonia).
For the realization of the measurement campaign four complete measurement stations are provided and installed on four previously mentioned sites. The height of the towers is 50m, this is a trade off between being as close possible to hub heights of today's wind turbines (80 m or higher) and reducing cost of measurements towers.



The measurements system is consisting of four three cups anemometers, two wind direction vanes and thermometer (fig. 1.a and 1.b). All sensors are by NRG Systems Company, USA and high quality anemometer on the top of the towers are made by RISO, Denmark. The wind speed sensors are calibrated according to the MEASNET standard with accuracy class of 0,1m/s, which is used by the wind industry in Europe. Two of the anemometers are on the top of the mast at 50 m height, the third is on 30 m height and the last is on 10 m height above the ground. The wind direction is measured in two different heights for redundancy. Temperature is measured at 2 m, which is a meteorological standard.
In addition to sensors there are data loggers (fig. 2) inside weather proof cabinets with communication capabilities over GSM line. The data loggers is an internet ready, ultra-low power microprocessor-controlled data logging system, specially designed for the wind energy industry. Together with the data logger there is iPack system, which enables transfer of data via GSM to the local Internet provider than emails are sent to the final users. The iPack device is connected to the back of the logger and its battery is charged with solar panel.
The logger has a 12 channel, 6 counter inputs for wind sensors or other frequency signals and 6 analog inputs for wind direction, temperature, barometric pressure, etc. The storage medium is non-volatile FLASH 16 MB multimedia card, which provides 2 years time of data storage.

The sensors are sampled every 2 seconds, but the average values, minimum and maximum values, standard deviation are calculated for time interval of every 10 minutes, according IEC 61400-12. The data loggers are sending data once per day to dedicated computers.
The data are processing and archiving in a well-defined, systematic and consistent manner. All raw data received via remote communications are archiving monthly into a complete database. The raw files are converting to engineering values (wind speed, wind direction, temperature) using appropriate software.
Incoming data are checking regularly for any signs of equipment damage and/or malfunction. The completeness of the received data files are analyzing weekly and the data are analyzing on a bi-weekly basis for errors and equipment failures. The need for accuracy is usually higher for wind energy projects than for weather forecasting. The analysis of data will be performed in close cooperation with the local meteorological office.

IV. OBTAINED RESULTS

The obtained resilts are shown on the figures 3 to 7. Figure 3 presents the average values of wind speed during one month

for one of the locations, the obtained value is 6.3 m/s. Next figure 4 presents wind rose for the same location and same month. Dominant direction of the wind is north-northwest. Relative frequency distribution of wind speed for the same location and month is shown on fig. 5.

The short analysis of obtained results from the four anemometers mounted at one measurement station for 7 months is presented in fig. 6.

Next phase of the project is to analyze all results obtained from the measurements and to prepare feasibility study of the chosen locations.

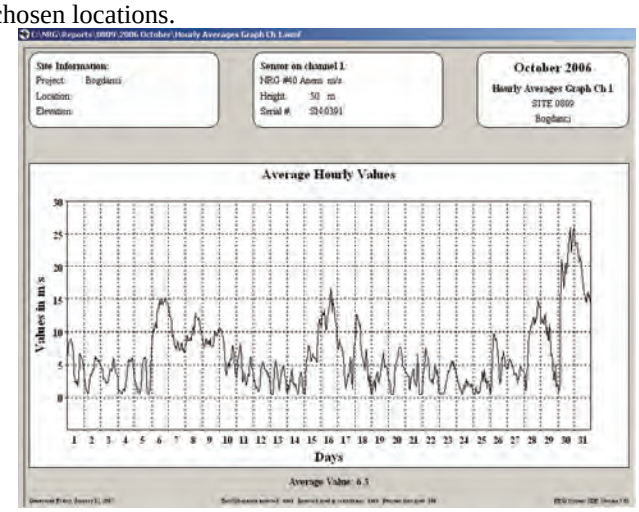


Fig. 3 Average 10 minutes wind speed for one month

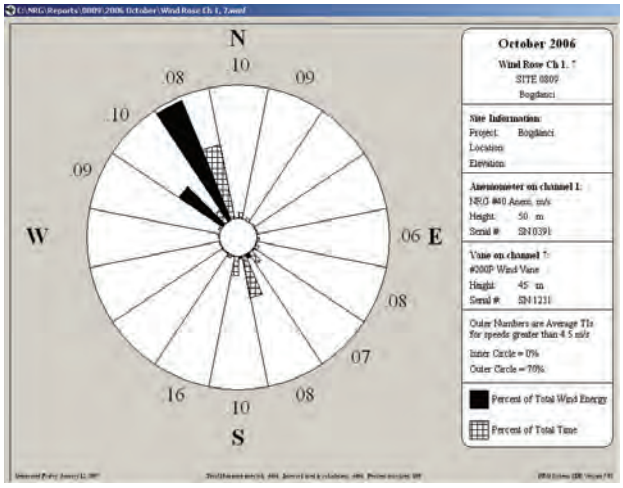


Fig. 4 Wind rose for one month

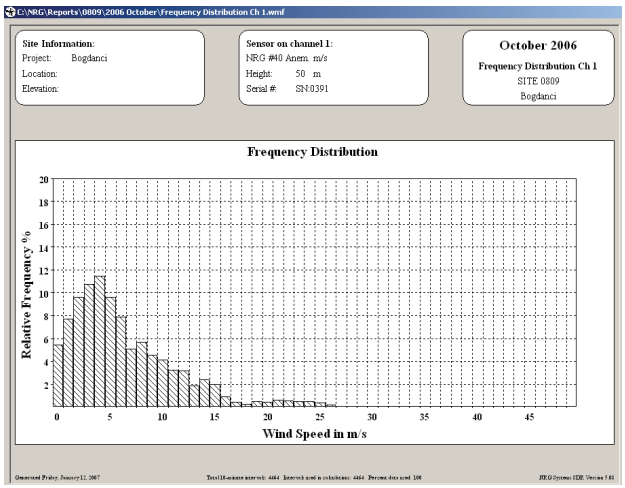


Fig. 5 Relative frequency distribution of wind speed

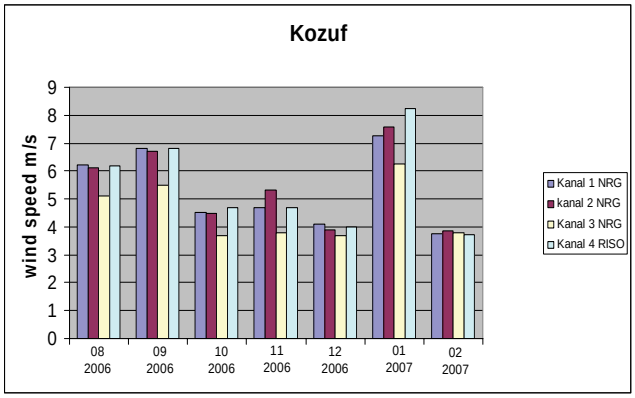


Fig. 6 Average wind speeds from 4 sensors for 7 months

V. Conclusion

The paper explains latest developments considering exploration of Macedonian wind resources. A Wind Atlas of Macedonia was created in 2005. The maps formed the basis for a GIS-based selection of 15 prospective sites where measurements should be done. Another five additional sites were proposed by ESM (now ELEM). From those 20 sites, after on sites visits four most promising sites were chosen for the measurement campaign.

The four complete measurement stations were installed in June, 2006. The planned measurement campaign is going for ten months and will last another 3 - 6 months. The final goal is to provide reliable results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms.

VI. References

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