ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XIV [2016] – Fascicule 2 [May]
ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-accessmultidisciplinarypublication
of theFaculty of Engineering Hunedoara

[1]Predrag ŽIVKOVIĆ, [2]Mladen TOMIĆ, [3]Dušan PETKOVIĆ, [4]Ivan ĆIRIĆ, [5]Žana STEVANOVIĆ, [6]Dragana DIMITRIJEVIĆ, [7]Sanja DOBRNJAC, [8]Milica ĆIRIĆ

POSSIBILITIES OF WIND ENERGY USAGE IN THE SKI CENTER KOPAONIK

[1,3,4,6] University of Niš, Faculty of Mechanical Engineering, Niš, SERBIA
[2] College of Applied Technical Sciences Niš, Niš, SERBIA
[5] University of Belgrade, Institute for Nuclear Sciences Vinča, Belgrade, SERBIA
[7] University of Banja Luka, Faculty of Technology, Banja Luka, BOSNIA & HERZEGOVINA
[8] University of Niš, Faculty of Civil Engineering and Architecture, Niš, SERBIA

ABSTRACT: Obtaining of all acceptable locations is one of the main tasks for siting of wind turbines. However, ecconomical factors are usually very limiting. One of the possibilities to increase the rentability of the wind farm is to reduce the transport loses, as well as the initial investment, by using produced energy as close to the production site as possible. This paper focuses on the possibilities of Kopaonik mountain wind potentials usage in the existing extensive ski resort. The estimations were obtained using the WAsP simulation software. The results are compared by means of the quality and quantity of the wind data and capacity factor. Finally, the economical analysis of the acceptabillity of the installing of wind turbines was done. This paper is concerned by the National Program of Energy Efficiency, project number: TR33036, funded by the Government of Republic of Serbia.
Keywords: wind power assessment; complex terrain; CFD; WAsP; ski center

1. INTRODUCTION

The most assesments of the classical fuel resources, mostly fossil, clearly marks the fact that their resources, especially for oil, are close to the end. From the other side, the global heating and pollution problem, mostly caused by large emissions of flue gasses from power plants and engines, arises constantly. Needs for energy constantly rises, so even the reachest states experience the energy problems (as the two-day California energy system collapse). All this facts points to the necessity of transition to the sustainable development, especially to the usage of renewable energy sources, among which the wind energy clearly takes its place, considering its large potentials, purity and availability. The present constrains are mostly of financial nature.

Having all that in mind, the most important task is the siting of wind turbines. For that purpose, the wind atlas method is developed, which became the best for use with the fast development of computers. The task itself is comparativelly simple when the terrain considered is flat. But, in terrains with complex orography, situation is much more complex. With change of wind turbine position of only few dozens of meters, their potentials for energy production can be drastically altered. It can be shown that simple, linear models (as the one used for WAsP) can't estimate correctly the wind energy potentials in the terrain where the ruggedness index exceeds 0.3.

Terrains with complex orography can have larger potentials than flat terrains. This is caused with the speed-up effect, which also depends on the main wind directions. Considering all above mentioned, the necesity of using more complex, CFD software, which is solving the complete set of conservation equatios, is obvious. The present practice is that the change of wind turbine location is justified if the potentials increases at least for 1%.

2. MATHEMATICAL MODEL

Considering the need to obtain the results as soon as possible, the best micro models were extracted from the larger macro models (well known nesting technique) using the fast linear software WAsP [4]. As the difference in the obtained results for annual energy production of a wind farm is shown to be about 30% between the linear and CFD softwares, final results are decreased for 30%, while using only WAsP.

The linear model is expressed by:

- continuity equation: $\frac{\partial}{\partial x_i}\left(\rho\, U_i\right)=0$
- logaritmic vertical wind profile: $U_z=\frac{U_*}{\kappa}\left(\ln\frac{z}{z_0}-\psi\right)$.
- Weibull distribution equations: $f(U)=\frac{k}{A}\left(\frac{U}{A}\right)^{k-1}\exp\left[-\left(\frac{U}{A}\right)^{k}\right]$, $F(U)=\exp\left[-\left(\frac{U}{A}\right)^{k}\right]$

Representative of the linear software packages is WAsP [1], [4]. It calculates the speed-up effects of the hills, taking into consideration the effect of redistribution of energy in the flow from the component in the flow direction into the vertical component.

3. KOPAONIK WIND POTENTIALS

Scope of this paper is the Kopaonik mountain (also known as *Silver mountain*) region, which is situated in the central southern part of Serbia. It is the largest mountaineous region in Serbia, which streches from northwest towards southeast for about 75km, with widest part in the middle of about 40km. Large part is conserved as the Kopaonik national park. It is the largest ski-center in Serbia. The highest altitude is the Pančić's peak at 2017m asl. There is a large highland area with many peaks, as Karaman (1934m), Gobelja (1834m), etc. South of the Pančić's peak, there are many single rises: Čardak (1590m), Šatorica (1750m), Oštro koplje (1789m).

With about 200 sunny days annually, Kopaonik is also called *Sunny mountain*. Southern, high and open position averts the clouds, keeping the cold air in the surrounding low areas, so the winter temperatures are not too low, which is very important considering the possibility of wind turbine blade frosting. Average yearly temperature is 3.7°C. Snow lasts from mid november through may, about 160 days annually. Precipitation levels are over 1000mm annually.

Ski center Kopaonik has about 62km of tracks and 25 ropeways with owerall capacity of 32.000 skiers per hour.

Chosen wind turbine type is Enercon E-82, with unit power of 2MW. Considered micro model was choosen by former simulation on the bigger model, from which, using the nesting technique, named model is obtained.

For the turbine siting the method of wake loss minimization and maximal annual energy production was used. Also, the recommendations about distance between wind turbines for the siting were as follows: in the wind direction minimally 7D (D – rotor diameter) and in the normal direction 4D.

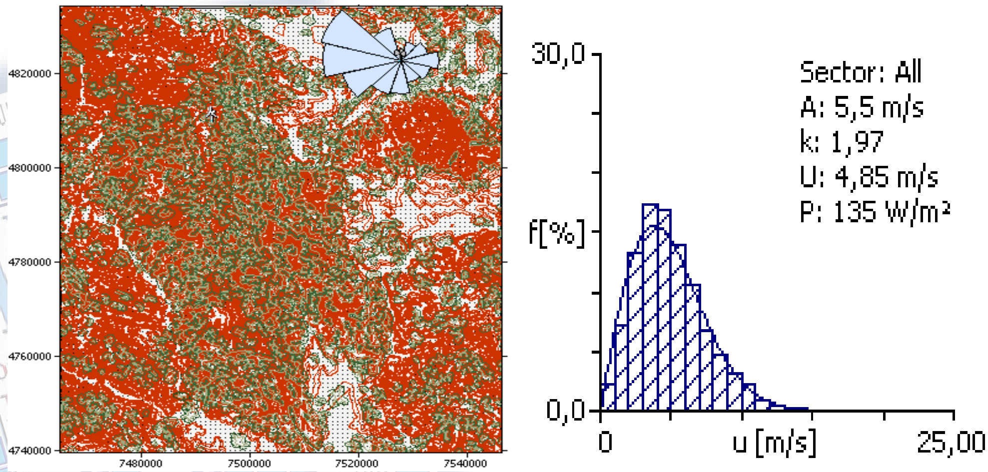

Figure 1. Macro model with wind rose (left) and Weibull distribution (right)

After the simulation were done, using the nesting technique, the micro model is obtained, and the field of annual energy production (AEP) is presented on the following figure:

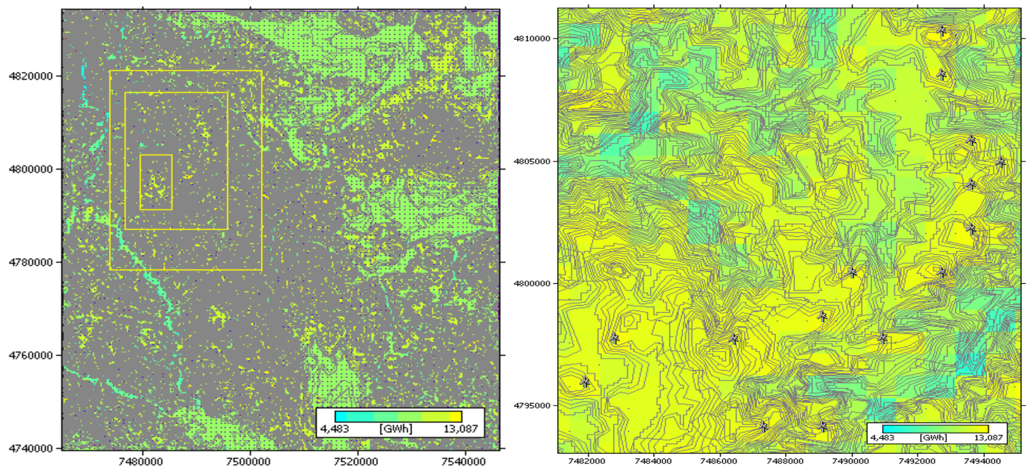

Figure 2. Nesting (left) and AEP field with 15 turbine wind farm disposition (right)

From the figure 2, one can notice that only the best locations are considered, as there are possibility for more locations to choose.

Table 1. AEP data for the 15 turbine wind farm Kopaonik

Parameter	Total	Average	Min	Max
Gross AEP[GWh]	188,79	12,59	12,26	12,99
Net AEP[GWh]	188,65	12,58	12,26	12,99
Wake loss [%]	0,08	-	-	-

Table 2. Seasonal assessment of possible wind farm electrical energy production

Annual	October-March	April-September
50.23 [GWh]	30.06 [GWh]	20.17 [GWh]

Table 3. Seasonal average electrical energy consumprion for the ski-center Kopaonik

Annual	October-March	April-September
18.66 [GWh]	13.75 [GWh]	4.91 [GWh]

Stable wind data were obtained from the main meteorological station Kruševac. As the turbine acceptable wind speed is in the range of 2÷25m/s, only 38,16% of the wind data are in the acceptable range. Considering this, as well as the overestimation by the used software, the capacity factor (ratio between possible AEP and max AEP) is calculated to be C_P=0.21. It is considered that the ecconomicaly acceptable locations are with C_P=0.25 or larger.

4. ECONOMICAL ANALYSIS

Economical analysis is one of the most important parts of every project. Renewable energy, including wind energy, is not an exeption. Having in mind current prices of wind turbines, state of the global and local financial markets, and the fact that the local infrastructure is not very developped, preliminary financial analysis was done. The initial assumptions are: the farm will operate for 25 years; initial investment is 49.5 million EUR; subventions will be 10%; annual discout rate will be 10%; annual inflation will be 7%; increase of the electricity price will be 12% per annum. Expected electricity price is 0.104EUR. The estimated financial indicators are shown in the following table.

Table 4. Financial indicators

FINANCIAL INDICATORS			
Rate of income (year 01)	ROI	9.90	[%]
Simple payback time	SPB	8.32	[year]
Net present value	NPV	996645829	[EUR]
Internal rentability rate	IRR	21.88	[%]
Dynamic payback time	DPB	9.53	[year]
Benefit/cost ratio	B/C	188.25	[-]
Lifelong cost savings	LCS	10977789	[EUR/ year]

Using above mentioned financial indicators, it was calculated that annual income of the wind farm Kopaonik could be about 5.23 million EUR. It shows that the project payback time is about8 years, which gives hope that such a project could be realized, as this is borderline for such projects.

5. CONCLUSION

Wind energy is one of the fastest growing renewable energy resources. Most of the EU members are using it widely. Yet, the available usable locations are not limitless. This gives opportunity to the less developed countries to use the available funds, in the scope of 20% of energy in Europe to be produced by renewable sources.

Koponik region is relatively far from the power sources. Installing wind turbines could significantly improve the quality of the energy supply in this area, which is very desirable, having in mind the extensive ski-center, the largest in Serbia, and one of the largest in Europe, with tendency of expanding the cappacities.

According to the data presented in the Tables 2 and 3. it is obvious that the excess energy production compared to the consumption is almost 80% for the summer and about 60% for the winter season. Such excess energy can be sent to the distribution network, towards other consumers. Closeness of the large energy consumer as the ski-center Kopaonik can reduce the network losses, as the consumers are almost on-site.

ACKNOWLEDGEMENTS

This paper is part of the work within the National Program of Energy Efficiency, project number: TR33036, funded by the Government of Republic of Serbia.

Note:

This paper is based on the paper presented at The 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, organized by the University of Banja Luka, Faculty of Mechanical Engineering and Faculty of Electrical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA (29th – 30th of May, 2015), referred here as[5].

REFERENCES (BOLD)

[1.] Schaffner B., Tonsberg, N., (2003). Wind Modeling in Mountains: Intercomparison and Validation of Models, study for METEOTEST, Bern, Switzerland and VECTOR AS, Norway.

[2.] Stevanović, M. Ž. (2008). Numeričkiaspektiturbulentnogprenošenjaimpulsaitoplote. Univerzitet u Nišu, Mašinskifakultet, Niš.

[3.] Živković, M. P. (2006). Procena energije vetra na terenima kompleksne orografije – uporedna analiza metodologija. Univerzitet u Nišu, Mašinskifakultet, Niš.

[4.] Živković, M. P. et al, (2013). Wind energy potentials of Vlasina region. DEMI 2013 Conference Proceedings, p. 809-814.

[5.] Živković, M. P. et al, (2015). Possibilities of wind energy usage in the ski center Kopaonik, Electrical and Mechanical Engineering and Information Technology – DEMI 2015, Bosnia & Herzegovina

ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering