Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

OPTIMIZATION AND REDESIGN OF VERTICAL AXIS WIND TURBINE FOR GENERATOR OF INDEPENDENT SOURCE OF ENERGY

KACOR, P[etr]; MISAK, S[tanislav] & PROKOP, L[ukas]

Abstract: *The paper deals with one of the possibility how to optimize the basic construction design of vertical axis wind turbine by the help of finite elements method. There is used the commercial software CFX from ANSYS system for analysis of our problem. The main goal of optimization is to improve and increase the basic output parameters of wind motor of original construction design.*
Key words: *Wind Turbine, CFD, CFX, Optimization, Design*

1. INTRODUCTION

In present time the Horizontal Axis Wind Turbine (HAWT) is the most used type of wind turbine for production of electric energy from wind. There was a wide expansion of HAWT systems installations in the recent 25 years at whole world. (Manwell et al., 2009; Patel, 1999) HAWTs are mainly built for powers range from 10kW to units of MW. It usually needs higher velocity of wind for proper operation and also device for optimal positioning and turning of propeller blades. (Paraschivoiu, 2002; Eriksson, 2008) When we need lower range of power the use of Vertical Axis Wind Turbine (VAWT) will be better choice.

Main advantages of VAWT are wind direction independency, very simple design, low cost and possibility to install it for example on the roof of buildings in city. (Li et al., 2008) Design of VAWT contains only several parts. Electric generator usually serves like basic supporting structure and can be placed at ground level. Most often 3 or 5 pieces of vertical blades (H-rotor) are directly mounted by simple blade holders to extended shaft of synchronous generator. It forms uniform assembly without any gear-box, yaw mechanism etc. (Muller et al., 2009)

By means of referred advantages VAWTs still have not performed well in the commercial wind turbine market.

2. OUTPUT PARAMETTERS OF VAWT

There is used the hybrid system (VAWT with H-rotor + photovoltaic panel) for street lightning at area of campus of VSB Technical University in Ostrava. The output of this hybrid system serves for charging the battery unit which then provide output power to supply the highly luminous LED luminary. Photovoltaic panel works fine and correctly but VAWT does not. Parameters of VAWT are stated in the Tab. 1. and they are directly specified by the manufacturer.

Nominal Power	200 W
Turbine Diameter	0,8 m
Working Wind Speed	4-25 m/s
Safe Wind Speed	40 m/s
Nominal voltage output	AC 31V
Nominal rpm	350 1/min
No. of Blade/Length	5/1,5 m
Nominal Wind Speed	10 m/s

Tab. 1. The parameters of VAWT from manufacturer

Before mounting of VAWT on the lighting column the vertical turbine and synchronous generator with permanent magnets were tested in the laboratory and also basic characteristics were measured. The chart on Fig. 1 presents the comparison of output power characteristics of VAWT assembly at output terminals of generator.

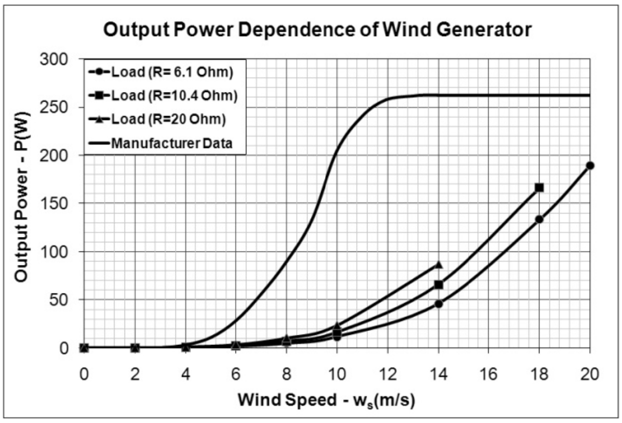

Fig. 1. Output power-wind speed characteristic of VAWT

As you can see the output power of generator is in strong dependence of load The VAWT needs higher wind velocity for proper operation. Briefly speaking, the nominal parameters are not fulfilled. There is probably wrong design of wind turbine or bad output power-wind speed characteristic provided by manufacturer of VAWT.

3. OPTIMIZATION OF THE VAWT DESIGN

Because of low power of VAWT and bad output power-wind speed characteristic we have to change the design or make some optimization steps. One way how to improve output parameters of VAWT is to use finite elements method and to work with numerical model of wind turbine. (Howell et al., 2010)

For optimization we have used the CFD software (CFX ANSYS) and model of VAWT H-rotor. Basic CAD geometry of original design of H-rotor is shown on Fig. 2A part. There is also shown one of the new analyzed designs with manger (semi-cylinder) shape of blade on Fig. 2B part.

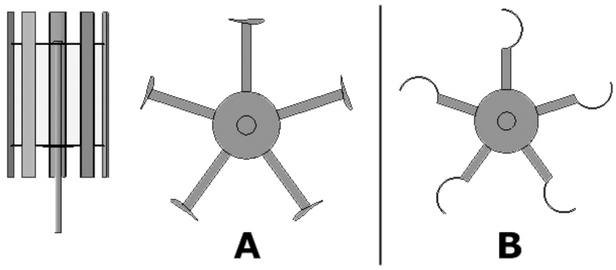

Fig. 2. Original and the redesigned rotor of VAWT

The main parameters from CFD analysis for checking are static torque (Ts) at braked rotor and value of torque (T_W) at nominal rpm speed of generator (350 min^{-1}). Basic prediction for all performed solutions is wind velocity with value of v_W= 10 m/s flowing from left side of the CFD model.

4. OUTPUT RESULTS FROM CFD ANALYSIS

In the first step of simulation is solved the original design of H-rotor of VAWT to find out the output static torque. Its value is only T_S= 1.8Nm. As the rotor increase its rotation speed the output torque decreased to value aprox. T_W= 1.2Nm at nominal rpm n_N= 350 min^{-1}.

Practical observation and measurement of the wind turbine in laboratory confirmed this fact. It also has shown that the layout of wind turbine is very poor with ratio length of blades to diameter of turbine: 1.8/0.5 =3.6. The power plant does not even reach 1/8 of the power output guaranteed by the manufacturer. Otherwise, the required output is reached only at very high wind velocity aprox. v_W= 20 m/s.

One possibility how we can get higher torque at the same diameter of turbine and length of blades is increasing of the blade surface. Manger (semi-cylinder) shape of blades is well known, cheap and simple technical solution.

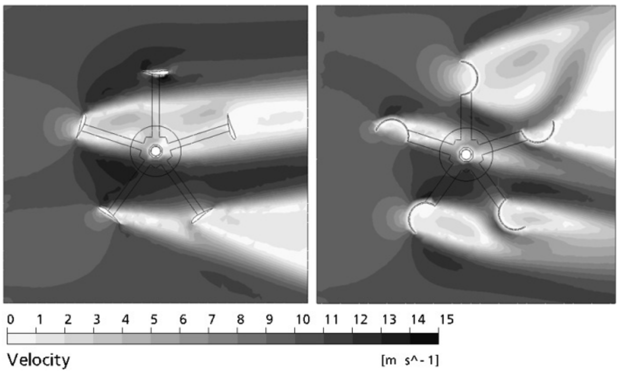

Fig. 3. Velocity profile at original and new designed rotor

There is shown the comparison of velocity profile at CFD model of original and optimized shape of rotor on Fig. 3. Model is made for analysis of static torque and wind speed v_W= 10 m/s. As we could expect the output static torque is higher (aprox. 3-times) in case of manger shape of blades. Its value is T_S= 5.4Nm. At nominal rpm of generator the torque reaches T_W= 4.8Nm.

Fig. 4 presents CAD model and CFD velocity profile solution of the other new design of wind turbine. It contains circular blades on the rotor and fixed circular blades on the outer stator.

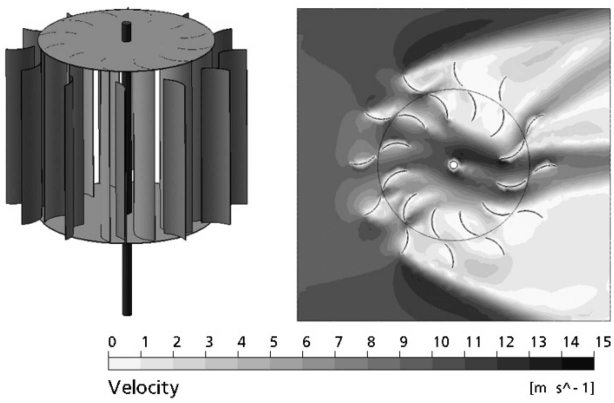

Fig. 4. The new design of vertical axis wind turbine (Lafond)

Basic requirements of this design were less diameter of turbine and shorter length of blades (D= 0.5m, L=0.5m). Also shape of construction elements (section of circle) has to be as simple as possible.

The value of static torque computed from CFD model balances between values of T_S= (3.2÷3.5)Nm according to actual position of blades. By higher number of blades on the rotor we can rapidly decrease imbalance of torque. Turbine with circular shape of blades has lower torque but it is able to work with very low wind speed.

5. FINAL CONCLUSION

The original design of VAWT in connection with a synchronous generator is designed primarily for off-grid work and currently it works as one of the autonomous sources for supplying of lighting that are operated at the VSB-TU Ostrava.

This paper shows the possibilities of using CFD analysis for optimizing wind turbine design. As the laboratory measurement and CFD analysis indicated the original design of VAWT is not optimal and the wind turbine does not reach necessary parameters.

Optimizing of VAWT made by help of CFD simulation served for real construction of the new vertical turbine with better parameters. As the paper shortly presented the CFD analysis play the important part in confirmation of concepts. Mutual comparison of simulated and measured values is also very significant.

At this time the monitoring of overall functionality of the hybrid system is being prepared from the point of view of power output flow and then the measured data will enable to assess the overall efficiency of proposed system.

6. ACKNOWLEDGEMENTS

The work described in this publication is a part of projects: Research of the Reliability of Power Systems in Connection with Non-traditional Ecological Sources of Energy and Valuation of Unsupplied Energy, code: MSM 6198910007, and also: Using of Hybrid Renewable Sources of Electrical Energy, code: SP/201073.

7. REFERENCES

Manwell, J.; McGowan, J. & Rogers, A. (2009). *Wind Energy Explained: Theory, Design and Application*, John Wiley & Sons, ISBN 978-0-470-01500-1, New York

Paraschivoiu, I. (2002). *Wind Turbine Design with Emphasis on Darrieus Concept*, John Wiley & Sons, ISBN 2-553-00931-3, New York

Patel, M. R. (1999). *Wind and Solar Power Systems*, CRC Press, ISBN 0-8493-1605-7, New York

Eriksson, S. (2008). *Direct Driven Generator for Vertical Axis Wind Turbines,* Acta Universitatis Upsaliensis, ISBN 978-91-554-7264-1, Uppsala, Sweden

Muller, G.; Jentsch F. & Stoddart, E. (2009). Vertical axis resistance type wind turbine for use in buildings, *Renewable Energy,* Vol., 34, May 2009 Pages 1407-1412, ISSN: 0960-1481

Howell, R.; Qin, N.; Edwards, J. & Durrani, N. (2010). Wind tunnel and numerical study of a small vertical axis wind turbine, *Renewable Energy,* Vol., 35, February 2010, Pages 412-422, ISSN: 0960-1481

Li, Y.; Tagawa K. & Liu W. (2008). Wind tunnel test on a straight wing vertical-axis wind turbine with attachment on blade surface, Available from: http://www. greenenergywindturbine.com/download/1816_Wind_Tunnel_Test.pdf Accessed: 2010-06-12