Simulation Modelling of Reasonably Application of Small Wind Power System in Bulgaria

Atanas G. Chervenkov[1]
Department of Theoretical Electrical Engineering
Technical University of Sofia
Sofia 1700, Bulgaria
e-mail: acher@tu-sofia.bg

Atanas Y. Yanev[2]
Department of Theoretical Electrical Engineering
Technical University of Sofia
Sofia 1700, Bulgaria
atanas.yanew@gmail.com

Abstract—**The possible application of a small wind power system, that can be deployed in many places in Bulgaria at low wind speeds, is considered. An analysis of small wind power system is done. A model of small wind power system is created in MATLAB. A dynamic time conditions of the wind power system operation have been carried out. The studied system is balanced to generating power from wind generator and variable load by means of battery. The total harmonic distortion THD of the system is very low. The electromagnetic compatibility of the wind system is observed. The requirements of the standards are satisfied.**

Keywords—application, electromagnetic compatibility, MATLAB, simulation, wind power

I. INTRODUCTION

Regarding to the economic development of modern civilization, the requirements for produced electricity in respect of environmental pollution are increasing continuous.

The recent “The European Green Deal” [1], requires exploring new options for using clean energy. The European Parliament has given its final approval to a binding EU-wide target of 32% share of renewable energy by 2030. According to statistics, 14% of EU electricity in 2018 is generated by wind farms, and wind power capacity in Europe has increased by 11.3 GW (data from windeurope.org).

Continuous growth of the capacity and the use of more powerful turbines contribute to increasing the percentage of wind energy. However, high-power wind farms are located in places where the wind speed is high and constant. Unfortunately, these plants are located far from electricity consumers, very often around an aquatic environment. This necessitates the transfer of the energy produced, which is inevitably linked to losses and further networks expansion is needed.

The main aim of this study is to be checked through simulation the possibility of efficient use of energy from wind generators in small sites remote from the electricity grid such as livestock farms, vegetable gardens, orchards, sheep farms etc. In addition, it is required to investigate the quantity and quality of produced electricity from small wind power system and compliance with the requirements for electromagnetic compatibility.

The use of renewable decentralized energy is a non-polluting solution. It provides the generation of a viable energy alternative at different points in the geography of a country or region. In addition, it provides a reduction in transmission losses and uninterrupted power supply in the event that the power supply site is away from the power grid. This concept of distributed generation, very close to consumption points, made in general by small power plants, has led to what is called micro-network, as opposed to the usual up to now large generating electricity plants, which support large and extensive distribution networks to power remote loads [2].

In the present work, small wind power system is investigated by modelling of the energy generated from the wind system and a supplying variable load.

II. CALCULATION OF WIND POWER ENERGY PPRODUCTION

The electricity generation from the wind power system using RETScreen Expert software tool is calculated [3]. Investigations of the wind potential are made. The places, located in different parts of Bulgaria, to determine wind values for low-power wind generators are investigated. A Snapshot of wind generation for one object in Fig. 1 is shown. In Table I some results of wind speed determination at 10m are given. The approximately calculation value of wind speed for simulation can be about 2.5 m/s.

III. DESCRIPTION OF WIND POWER SYSTEM

The wind power system is consist one renewable sources of small power (10kW) wind generator. The system is not connected to a distribution grid and power system supplies the AC loads. To store the generated electricity in the case of an absence of generating power, a rechargeable battery is used. The main purpose of the battery is to delivery power for operational needs for small amount of time in case of wantage.

TABLE I. WIND SPEED DETERMINATION

Location	Average Annual Wind Speed (m/s)
Sofia	2.3
Ruse	3.4
Sliven	2.2
Varna	3.3
Vidin	1.5
Pleven	2.6
Yambol	2.1

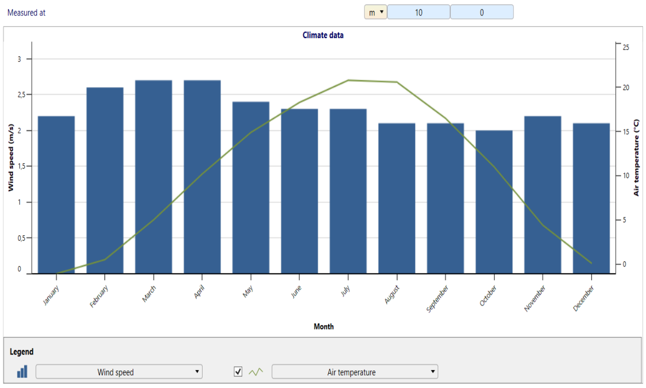

Fig. 1. Snapshot of wind generation

The transformation of the produced energy with DC-AC inverter is carried out. To restrict and optimize charging and battery discharge processes a controller is used. The configuration structure for the power system based on wind energy sources in Fig. 2 is shown.

The wind power generation system includes the following sub-system: wind turbine, charge controller, battery bank and inverter.

IV. Model of Wind Power System

The scheme of the wind power system in Fig.3 is shown. The entire system design of the wind energy system is simulated using SIMULINK. A 10-kW of wind power energy system as well as BESS (Battery Energy Storage System) was considered. Fig. 3 show the simulation schematic of wind power system.

The energy source is modeled using MATLAB software tool to analyze their work. A control technique is using to accomplish maximum generating power [3]. The simulation results show stability and reliability of the small wind system.

The parameters of the wind system elements are as follows.

Wind generator characteristics are: nominal mechanical output power - 12.5 kW; base power of the electrical generator – 10 kVA; power factor 0.9; base wind speed - 10 m/s; energy conversion efficiency (maximum power at base wind speed of nominal mechanical power) 0.8.

Loads characteristics are:

- *Load 1* - configuration - *Y* (grounded); nominal phase-to-phase voltage V_n - 385 V(rms); nominal frequency f_n - 50 Hz; active power *P* - 6000 W.
- *Load 2* - initial status open, switching times (s) - turned on at 5 s; configuration - *Y* (grounded); nominal phase-to-phase voltage V_n - 385 V(rms); nominal frequency f_n - 50 Hz; active power *P* - 4000 W.

Battery characteristics are: type Ni-MH, nominal voltage V_n - 300 V(rms); rated capacity - 6.5 Ah; initial state-of-charge - 30%.

An electronic converters used in wind power systems, are the major source of harmonics. The inverters use semiconductor devices with losses by the transformation of generated power to the output AC power [3].

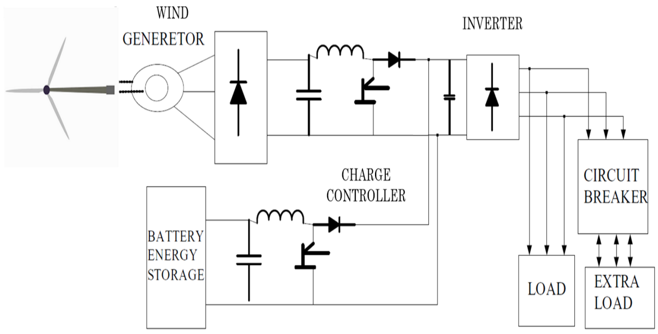

Fig. 2. Configuration of power energy system

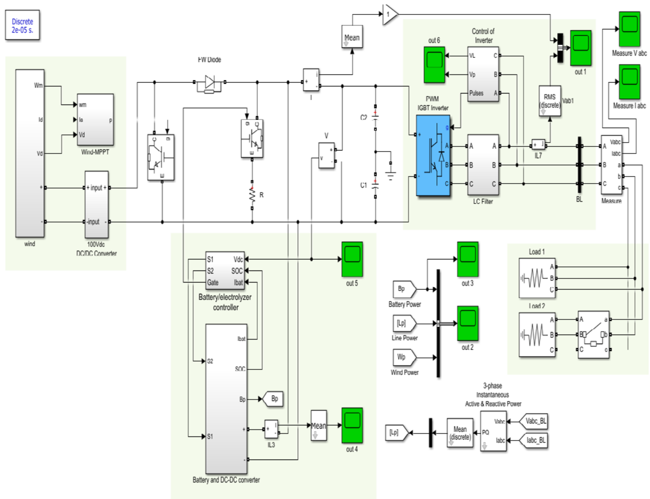

Fig. 3. Scheme of the studied wind power system

Pulse Width Modulation switching is the most commonly used way for the generation of AC voltage. PWM allowing for flexible control of the output voltage magnitude and frequency [3]. All PWM techniques generate harmonics and noise originating in the high dv/dt and di/dt semiconductor switching transients [3, 4].

It is therefore imperative to provide ways to eliminate harmonics [3]. LCL filter is often used to interconnect an inverter to the utility grid in order to filter the harmonics produced by the inverter [3, 5].

Very often voltage tracking is used to speed up the inverter control process. Voltage tracking speed is faster and also the voltage ripple gets reduced [6].

V. Simulations

A. Wind Speed and Load Power

The simulation study of system parameters are presented below. To predict their actual characteristics energy source is modeled accurately in SIMULINK.

A dynamic in time conditions of the wind power system operation is considered.

Simulation of different conditions of the wind system is performed. Some of these conditions clearly are observed below.

Duration of the simulation is 6 seconds. Load 1 constantly consumes 6000 W of energy for the whole duration of the simulation, while at the start of the simulation. Load 2 is not connected and does not consume energy from the system, since status of the circuit breaker is normally open. The switching time of circuit breaker of the load 2 is - the load 2 change its state and is turned on at fifth second till the end of the simulation.

The Table II shows how the winds speed and loads changes over time of the simulation.

The wind speed and loads over simulation time in Fig. 4 are shown.

B. Voltages and Currents in Load

The voltages and currents in the three phases of wind power system voltages are tested to evaluate electromagnetic compatibility.

The integrated voltages and currents in the three phases of load are close to sinusoid.

The simulation results of voltages in the load and the simulation results of currents in the load are shown in Fig. 5 and in Fig. 6, respectively.

C. Voltages and Currents in Inverter

The reliability operation of the system depends largely on the stability of the inverter output voltage.

If it creates a high level of harmonics, it will disrupt the normal operation of the load and it will cause additional losses.

TABLE II. WIND SPEED AND THE LOAD OVER TIME

Time (s)	Wind speed (m/s)	Load (W)	Description
0	2	6000	
1	3	6000	
3	5	6000	
4	10	6000	
5	3	10000	Load 2 triggered
6	3	10000	

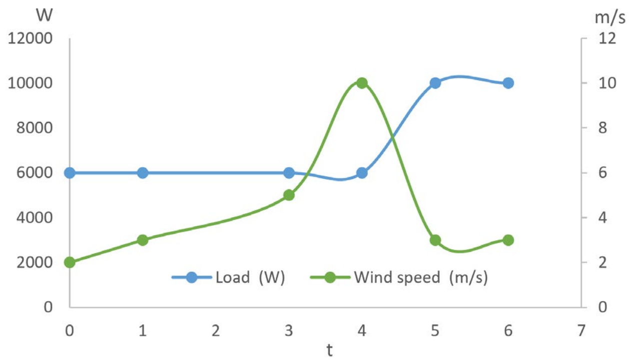

Fig. 4. Wind speed and loads over time

This can violate the normal electromagnetic compatibility situation.

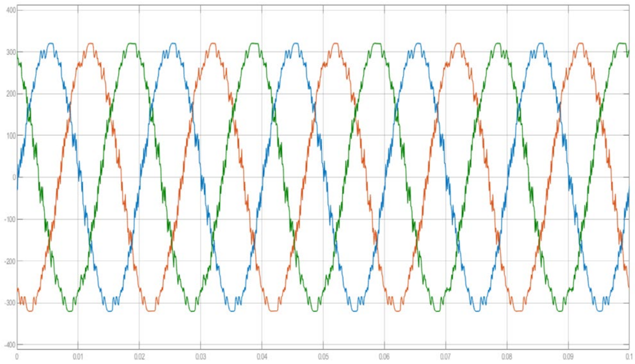

Fig. 5. Simulation results of voltages in the load

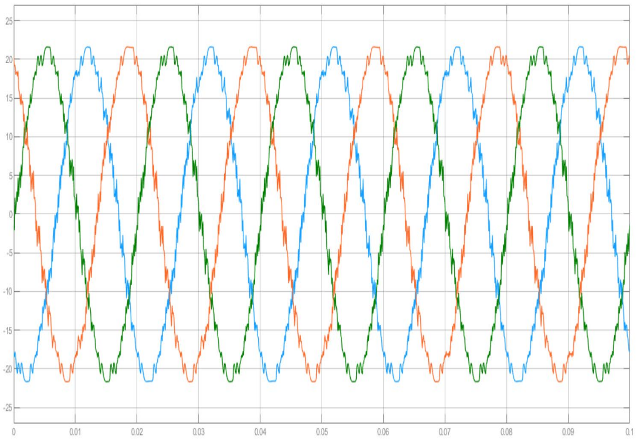

Fig. 6. Simulation results of currents in the load

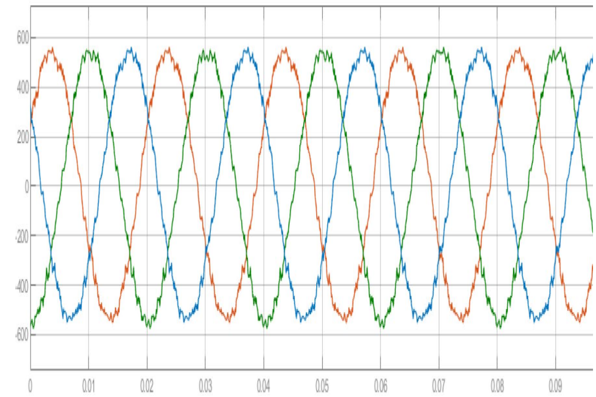

Fig. 7. Simulation results of voltages in the inverter

Therefore, the voltages and currents in inverter for electromagnetic compatibility are evaluated also.

The simulation results of voltages in the inverter in Fig. 7 are shown.

The existing voltages and currents in the inverter have a satisfactory shape, close to sinusoidal.

Because of that, the voltages and currents in inverter can't violate the normal electromagnetic compatibility.

D. Power, Voltages and Currents in Battery

The capacity of the used battery provides sufficient load power when the wind energy from the generator is reduced or missing. The battery power in Fig. 8 is shown.

The SOC of a battery, that is, its remaining capacity, is determined using voltage method. The voltage is influenced by the battery current due to electrochemical processes in the battery and its temperature [7]. Therefore, the remaining capacity is also examined. The estimate accuracy of SOC becomes increasingly important [8].

The voltage and SOS graphs of the battery in Fig. 9 are shown.

E. Harmonic analysis of Wind Power System

From the electromagnetic compatibility point of view of the studied wind power system, the most important is the amount of created harmonics.

The results of the harmonic spectrum and voltage THD of wind power system in Fig.10 are given.

The total harmonic distortion is relatively small and satisfies requirements of standard [9]. Since the studied system is standalone and has no electrical connection to other electricity facilities, it will not disturb their electromagnetic compatibility.

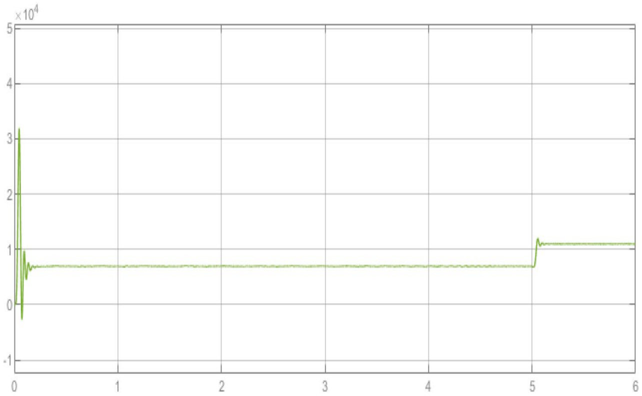

Fig. 8. Simulation results of battery power

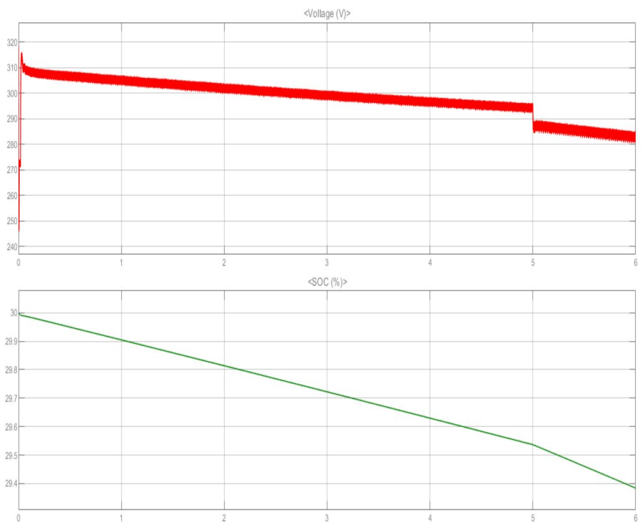

Fig. 9. Simulation results of voltages and SOC of battery

VI. Conclusion

The possible application of a small wind power system, which can be deployed in many places in Bulgaria at low wind speeds, is being considered.

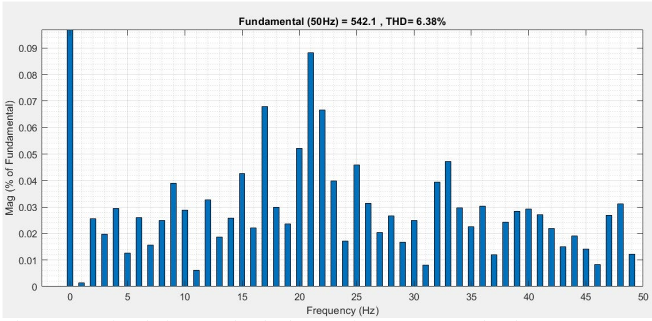

Fig. 10. Simulation results the harmonic spectrum and voltage THD

The investigations by modeling the dynamic change of the energy generated from the wind system and the load are performed. The studied system is balanced to generating power from wind generator and variable load by means of battery. The THD of the system is very low. The electromagnetic compatibility of the wind system is observed. The requirements of the standards are satisfied.

Acknowledgment

The authors would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support.

References

[1] European Commission, Annex to the communication from the commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, Brussels, 11.12.2019.

[2] J. M Andújar, F. Segura, and T. Domínguez, "Study of a renewable energy sources-based smart grid. Requirements, targets and solutions." 3rd Conference on Power Engineering and Renewable Energy (ICPERE), Yogyakarta 2016, pp. 45–50.

[3] A. Chervenkov, A. Yanev, and T. Chervenkova, "Performance analysis and modelling of grid-connected small photovoltaic system", Proceedings of XVI-th International Conference on Electrical Machines, Drives and Power Systems ELMA 2019, 6-8 June 2019, Varna, Bulgaria, pp. 500-503.

[4] S. Ivanov and Y. Ivanova, "Research of the impact of an active driver circuit with di / dt feedback on dc motor speed", Proceedings of IX National Conference with International Participation "Electronica 2018", May 17 - 18, 2018, Sofia, Bulgaria, pp. 51-54.

[5] T.M. Thamizh Thentral, A.Geetha, and C.Subramani, "Study of LCL filter performance for inverter fed grid connected system", Journal of Physics: Conference Series, 2018, 1000 012119, available on https://iopscience.iop.org/article/10.1088/1742-6596/1000/1/012119/pdf.

[6] M.Vinay Kumar and U.Salma, "Double integral slidind mode control approach for a three-phase gridtied photovoltaic systems", International Journal of Mechanical Engineering and Technology (IJMET),vol. 10, issue 01, pp. 1052-1069, January 2019.

[7] H.M.Robert and J.H. Collins, "Handbook of Energy Conservation", CBS Publishers & Distributors, 2007, vol. No.-I, pp. 122-138.

[8] W. Chang, "The state of charge estimating methods for battery: A Review", ISRN Applied Mathematics, volume 2013, Article ID 953792, p.7, http://dx.doi.org/10.1155/2013/953792

[9] IEEE Standard 519:2014 - IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.