EVALUATION OF COOPERATION WPP AND PV CONNECTED THROUGH THE SHARED TRANSFORMER TO THE NETWORK 22 KV

Tomas SUMBERA[1], *Frantisek STRIDA*[1], *Zdenek HRADILEK*[1], *Stanislav RUSEK*[1]

[1]Department of Electrical Engineering, Faculty of Electrical Engineering and Computer Science, VSB–Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava Poruba, Czech Republic

tomas.sumbera@vsb.cz, frantisek.strida@vsb.cz, zdenek.hradilek@vsb.cz, stanislav.rusek@vsb.cz

Abstract. *The article deals with evaluation the cooperation possibility of wind and solar power plants connected through the common transformer to the 22 kV network. Cooperation evaluation is, based on measured data, for wind power plant about installed capacity 2 MW and for solar power plant about installed capacity 1,1 MWp. In the next part of this article there is the analysis of suitable localities for construction of „hybrid system (WPP+PV)“ in the Czech Republic. The last part of the article deals with analysis of active power fluctuation of individuals electric sources compared with system WPP + PV and with evaluation the effects after system connection WPP + PV to the 22 kV network.*

Keywords

Wind power plant, solar power plant, availability ratio, active power.

1. Introduction

Wind and solar power plants have a great advantage compared to common sources of electric power that they don’t require neither any fuel during the electric power production nor produce any hazardous waste and waste products, especially CO_2. Conversion efficiency of wind power and solar radiation into electrical energy is very small. Wind power plant efficiency ranges average about 50 % and solar power plant from 15 % to 22 %, depending on the type of PV panel. A main disadvantage of wind and solar power plants is unstable and stochastic electrical energy supply, which is influenced by a large number of factors, such as seasons, day time, wind speed, solar radiation intensity, etc.

In the Czech Republic there is the lack of suitable localities construction of both wind power plants and solar power plants. From efficiency requirement of primary energy content, which is set out in Decree 475/2005 Coll. intended for the law implementation about renewable sources, it is assumed that average annual rate in the place of wind power plant construction up on high of the wind turbine rotor axis will be 6 $m \cdot s^{-1}$ and more. There doesn´t exist any notice that would regulate what should be minimal sum of solar radiation in the place of solar power plant construction, and most of large solar power plants are built in the place with low solar radiation intensity.

In this article we evaluate wind and solar power plants cooperation, connected through the common transformer to the 22 kV network. Evaluation is realized for July and October. The data are obtained from measurements from wind power plant with installed capacity 2 MW and from solar power plant with installed capacity 1,1 MWp, located in Moravian-Silesian region.

2. Cooperation Evaluation WPP + PV

Electricity supplies from wind power plant aren’t dependent on day time, as is the case of solar power plant, but only on wind speed. Wind power plant could cover electricity supply at night during cooperation WPP + PV.

Fig. 1 shows the instantaneous power waveforms at hourly intervals for July. Wind power plant availability ratio was an average about 14 % in July and solar power plant availability ratio was an average 18 %.

Fig. 2 shows the instantaneous power waveforms in the selected days. From the graph we can see that 8. 7. at 19:00 solar power plant stopped to supply electricity to the network and this supply was covered by wind power plant only. On 10. 7. we can see that between 13:00 and 14:00 supplied load increased significantly from value 1215 kW to 2050 kW.

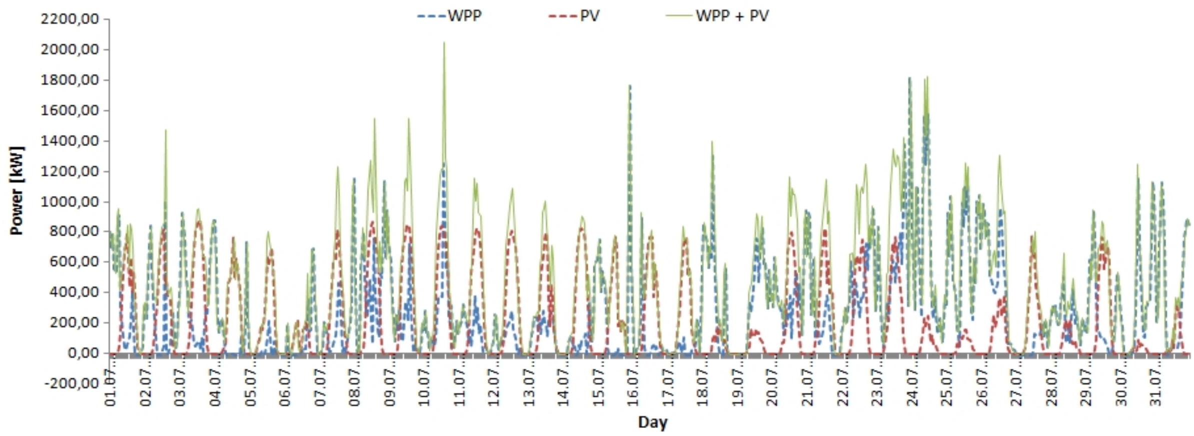

Fig. 1: The course of instantaneous power WPP, PV and WPP + PV – July.

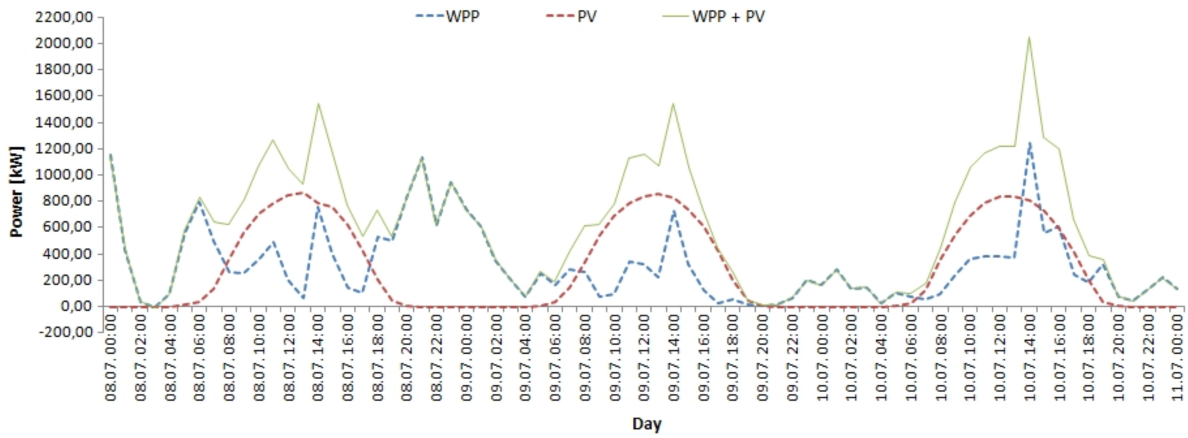

Fig. 2: The course of instantaneous power WPP, PV and WPP + PV – from 8. 7. to 10. 7.

Availability ratio of WPP + PV system would move about 15 % in July. The system would supply 355 MWh, from that 209 MWh wind power plant and 145 MWh solar power plant.

Fig. 3 shows the instantaneous power waveforms in October. The solar power plant availability ratio was an average 9 % in this month and wind power plant availability ratio was significantly higher than in July and its average value was 25 %. From the process we can see that electricity supply was mainly from wind power plant.

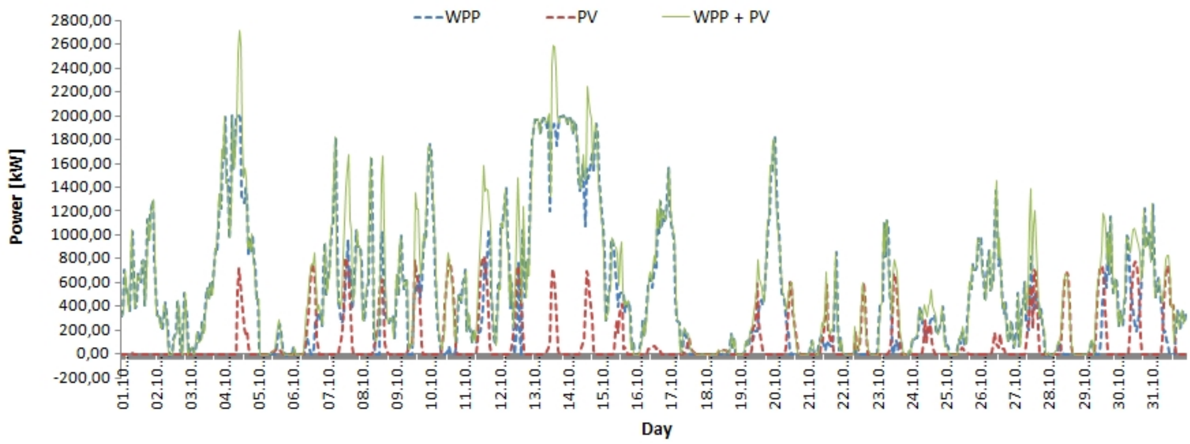

Fig. 3: The course of instantaneous power WPP, PV and WPP + PV – October.

Fig. 4 shows the instantaneous power waveforms in the selected days. From the process we can see that load supply from solar power plant was shorter about 4 hours than in July.

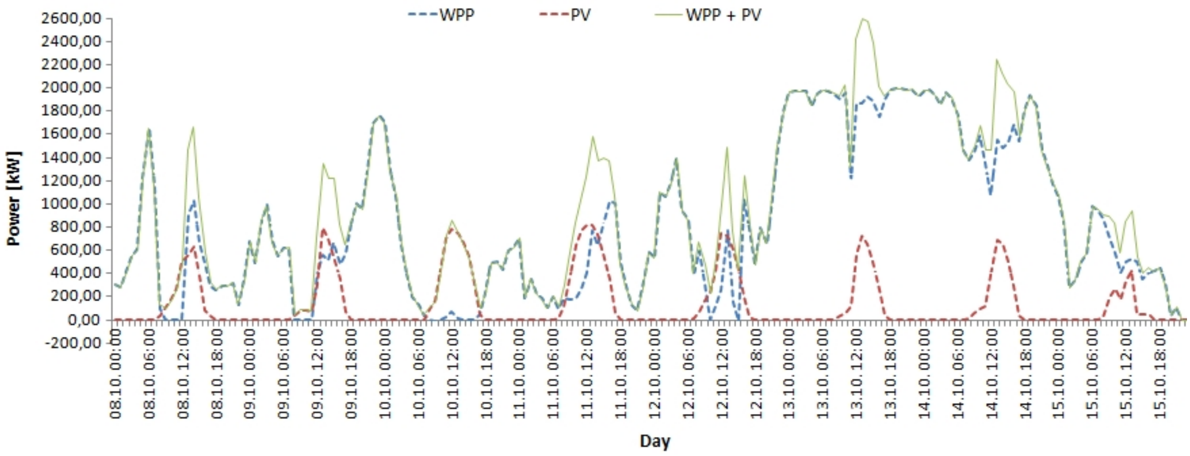

Fig. 4: The course of instantaneous power WPP, PV and WPP + PV – from 8. 10. to 15. 10.

Availability ratio value of WPP + PV would move about 19 % in October. The system would supply 440 MWh, from that 366 MWh wind power plant and 73 MWh solar power plant.

3. Suitable Localities Analysis for Hybrid System (WPP + PV) Construction

3.1. Wind Power Plants

Wind power plant is considered as one of the most growing power sources all over the world. By 2020 the share of electrical energy delivered from wind power plants should increase to 12 % from the total global consumption.

From efficiency requirement of primary energy content, which is set out in Decree 475/2005 Coll. intended for the law implementation about renewable sources, it is assumed that average annual rate in the place of wind power plant construction up on high of the wind turbine rotor axis will be 6 $m \cdot s^{-1}$ and more.

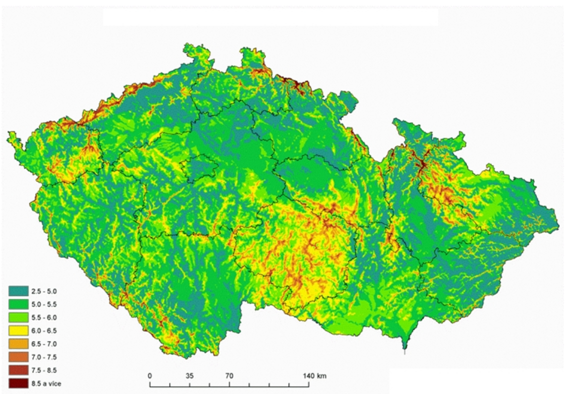

Fig. 5: Average wind speed field at a height of 100 m above the surface.

The Institute of Atmospheric Physics of the Sciences Academy in the CR prepared the map of average wind speed in the CR at the height 100 m above the surface, see Fig. 5 which is the typical rotor height at current wind power plants. Three combined models VAS, WAsP and PIAP were used to calculate the average wind speed.

3.2. Solar Power Plants

Solar energy is available around the world. However, it is an unstable energy source which is depended on daytime, weather, season and cloud amount in a given location.

This method of electrical energy production is quite capital intensive. In comparison to all other ways of electricity development, especially RES is 5 times more intensive. Crystalline silicon technology is used in this case. Solar cells can be either monocrystalline or polycrystalline and their efficiency is in the range from 15 to 22 %, specified lifetime is up to 25 years. However, producing photovoltaic cells itself is very energy intensive as the energy volume for producing one cell is delivered by one photovoltaic cell in our conditions over approx. 6 years.

The solar radiation incidence on the area of the CR does not have the same intensity at all places. The average annual sum of global radiation is in Fig. 6.

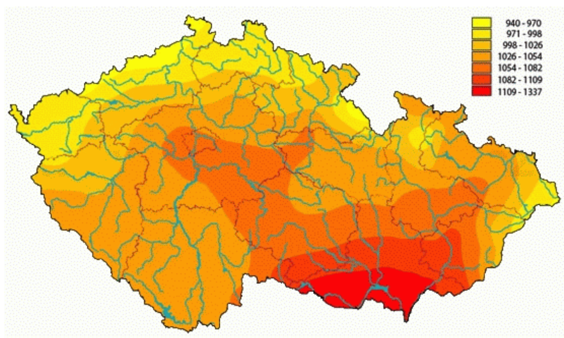

Fig. 6: Average annual sum of global radiation.

3.3. Localities Analysis

Suitable locality for hybrid system construction is located mainly in the Vysocina (Highlands). Average annual sum of global radiation is 1054 kWh·m^{-2} and average wind speed at the height 100 m above the surface is higher than 5,5 m·s^{-1}, as we can see in Fig. 7. Other suitable locality is the southern part of Southern Moravian region, where is average annual sum of global radiation, but average wind speed doesn't exceed 7 m·s^{-1}.

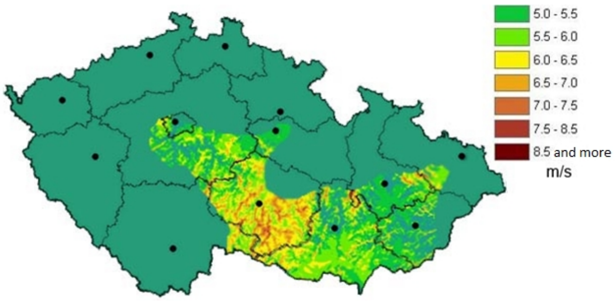

Fig. 7: Suitable localities for hybrid system WPP + PV construction.

4. Power Fluctuation Evaluation

Active power descending at wind power plants is caused by change of wind speed. Wind power plant works in wind speed range from 3 m·s^{-1} to 25 m·s^{-1}. Wind speed is dependent on landscape segmentation (meadows, forests, cities). Active power descending at solar power plant is caused by change of solar radiation intensity. Solar radiation intensity changes itself during the day and during the season. An important factor influencing the solar power plants is the solar panels rotation, clouds influence, panels pollution by dust and snow.

Difference frequency of active power among particular hours is shown in Fig. 8 and Fig. 9. The fluctuation size of active power is the most frequently below value 480 kW during July and below value 320 kW in October.

The graphs show that power descending is lower in comparison with the individual sources. It is important to perceive that the installed capacity of system was 3,1 MW, from that 2 MW at WPP and 1,1 MWp at PV.

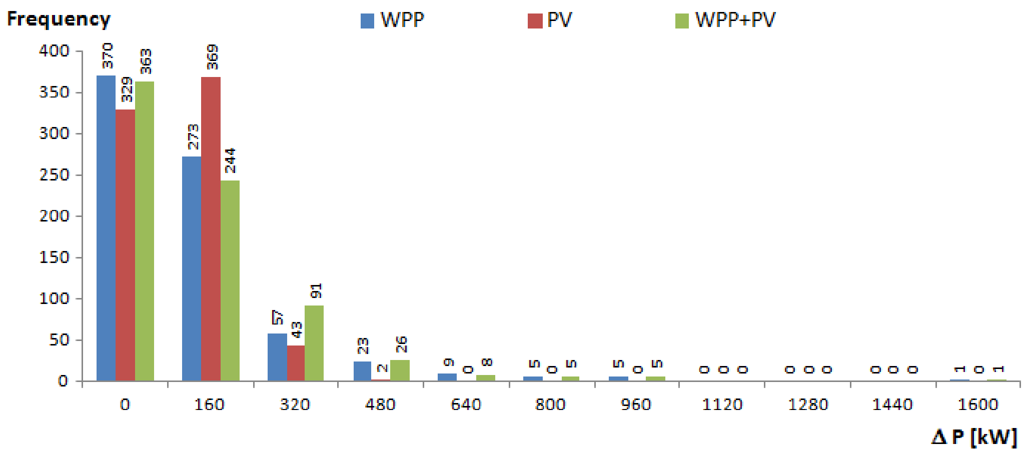

Fig. 8: Histogram ΔP – July.

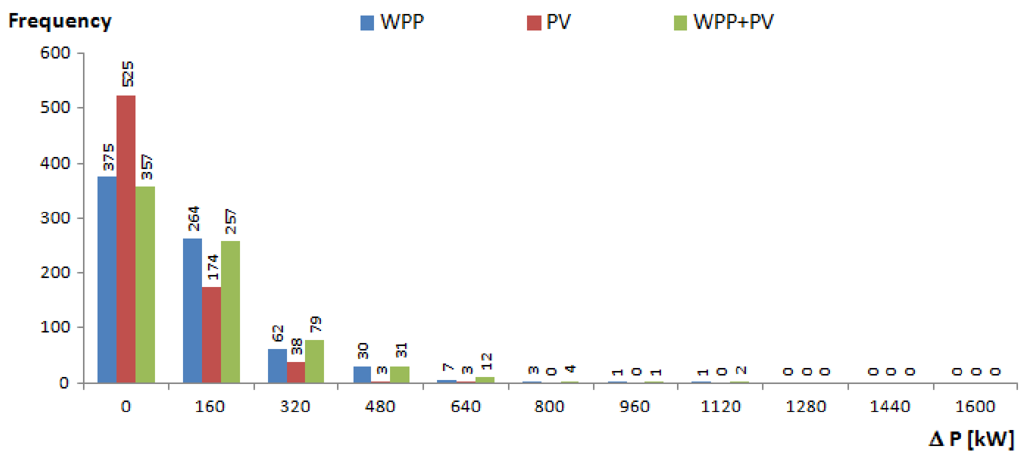

Fig. 9: Histogram ΔP – October.

5. Connection Influence to the 22 kV Network

Resources connection was evaluated on a real network in Moravian-Silesian region. There were modeled feeding substation area 110/22 kV mainly with 22 kV outside conduction. WPP and PV are connected to this network.

Furthermore there was created supply network model 110 kV from 400/110 kV supply substation to 110/22 kV supply substation. The area load 110 kV was modeled according to real data from winter measurement 2009.

There aren't available any loading data of particular distribution transformers 22/0,4 kV (DTS) for modeling power taking-off in 22 kV network. The DTS load was modeled by percentual loading of installed power DTS. Transformer in substation 110/22 kV is about 25 MVA power.

Maximum voltage peaks were selected for influence evaluation on the network and on the conditions in the substation. The Tab. 1 shows percentual voltage change after connection PV, WPP or WPP + PV system. The wind power plant was calculated with cos φ = 0,98 inductive and the solar power plant was calculated with cos φ = 1.

Tab. 1: The voltage difference at the connection point.

	dU [%] – 10th of July			dU [%] – 4th of October		
	PV	WPP	WPP+ PV	WPP	PV	WPP + PV
Connection point	0,50	1,78	2,25	0,57	1,12	1,67
Bus bar 110 kV	0,09	0,46	0,54	0,10	0,30	0,38
Bus bar 22 kV	0,04	0,17	0,21	0,05	0,11	0,16

In July, the value of sufferable voltage change ΔU= ±2 % was exceeded at the connection point, which is inconsistent with the rules for the distribution system. In this case is necessary to control power flow from the source, but this legislation does not allow yet.

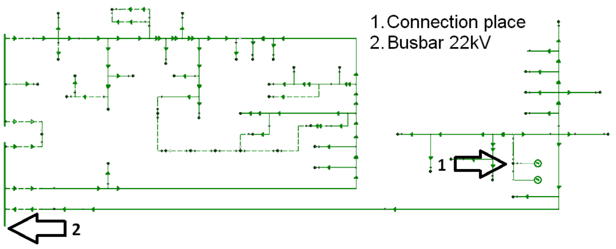

Fig. 10: Scheme 22 kV network.

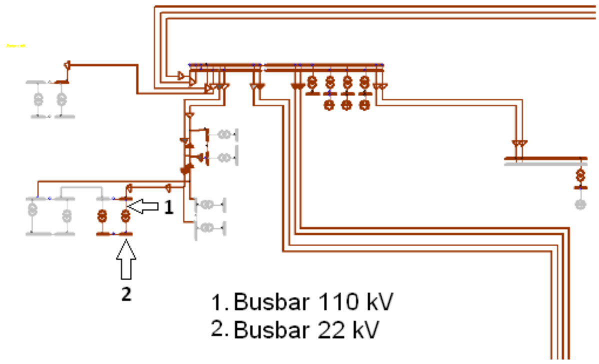

Fig. 11: Scheme 110 kV network.

6. Conclusion

WPP + PV system, Hybrid system, should have been kept in connection with suitable accumulation. In this system there isn't so frequent and significant change of power descending due to installed power than in separately working sources. Big system advantage is possibility of electricity supplies at night, when the solar power plant is out of order.

WPP + PV system contravenes rules for distribution system during working due to voltage increasing at the connection point, where is allowed voltage change ΔU= ±2 %. Part of the energy could be used to recharge the battery and the other part would cover power supplies to the network, in the case of accumulation connection to the system.

Acknowledgements

This contribution was prepared in the framework of research project CZ.1.05/2.1.00/03.0069 and SP2012/53.

References

[1] HRADILEK, Zdenek and Tomas SUMBERA. Reliability of electrical power supplies from renewable sources. In: *11th Conference Electric Power Engineering 2010*. Czech Republic, Brno, 2010, p. 401-406. ISBN 978-80-214-4094-4.

[2] PROKOP, Lukas, Zdenek HRADILEK and Tomas SUMBERA. Application of WPP Power Flows Measurement Methodology. In: *Conference Prognozawanie w Elektroenergetyce PE 2010*. Poland, Wisla, 2010, p. 121-122. ISBN 978-83-61118-82-4.

[3] HRADILEK, Zdenek and Tomas SUMBERA. Simulator of power forecasting gained from wind power plants. *Przeglad elektrotechniczny*. 2010, vol. 86, iss. 8, p. 196-199. ISSN 0033-2097.

[4] SUMBERA, Tomas. Reliability of electricity supply from renewable sources and possibilities predicting power. In: *8th Conference WOFEX 2010*. Czech Republic, Ostrava, 2010, p.

33-38. ISBN 978-80-248-2276-1.

[5] RUSEK, Stanislav, Frantisek STRIDA and Tomas SUMBERA. The Issue of Voltage Changes in Electricity Network in Relation to Operation of Wind Power Plants. In: *Conference ELNET*. Czech Republic, Ostrava, 2010, p. 27-34. ISBN 978-80-248-2349-2.

[6] HRADILEK, Zdenek and Tomas SUMBERA. Reliability and Predictions of Power Supplied by Wind Power Plants. In: *International Conference on Renewable Energies and Power Quality 2011*. Las Palmas de Gran Canaria, Spain, 2011, p. 254-259. ISBN 978-84-614-7527-8.

[7] HRADILEK, Zdenek and Tomas SUMBERA. Simulator for Prediction of Energy Obtained from Wind Power Plants. In: *12th Electric Power Engineering 2011*. Czech Republic, Kouty nad Desnou, 2011. ISBN 978-80-248-2393-5.

About Authors

Tomas SUMBERA was born in Moravska Trebova. In 2008 he graduated VSB-Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science, power engineering field. Today he is Ph.D. student in the Department of Electrical Power Engineering, Technical University of Ostrava and he applies himself to the issue of the wind and solar power plants influences to the distribution system.

Frantisek STRIDA was born in Prostejov. In 2007 he graduated VSB-Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science, power engineering field. Today he is Ph.D. student in the Department of Electrical Power Engineering, Technical University of Ostrava and he applies himself to the issue of networks optimalization with renewable energy sources.

Stanislav RUSEK was born in Havirov-Sucha. In 1981 he graduated VSB-Technical University of Ostrava, Faculty of Mechanical Engineering and Electrical Engineering, power engineering field. He graduated scientific postgraduate at Faculty of Electrical Engineering and Computer Science Brno, electrical machines and devices, in 1989. Post-graduate education at Faculty of Science Palacky University Olomouc in university education graduated in 1991. He was habilitated at the FEECS VSB Ostrava in 1991. He is professor from 2001.

Zdenek HRADILEK was born in Brno. After graduation of college education at Faculty of Electrical Engineering and Computer Science Brno University of Technology in 1962 he worked as a technician in company Southern Moravian power plants in Brno, than he worked as a major power-supply director in Heat-supply Ostrava and from 1966 until now he is at the VSB-Technical University Ostrava. His scientific preparation graduated by his candidate dissertation defending at the Brno University of Technology, power supply field, in 1972. He defended his doctoral thesis at the Czech Technical University in Prague in 1988. His pedagogical and scientific work is focused in power engineering field. He was appointed associate professor in 1977 and at the time of electricity department inception in 1978 he became its leader. He undertook this function, without pause, until 2009. He was appointed professor in 1988.