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Comparison of Few PV Systems with Fixed Stands in the Czech Republic

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Abstract: During last years we constructed few photovoltaic solar systems at the Czech University of Life Sciences Prague and we constructed few larger photovoltaic power plants as well. The constructions are with fixed or tracking stands, we used soft ridge concentrator in few constructions. We tested parameters of the photovoltaic systems especially the produced energy amount. There are compared few PV power plant in the Czech Republic with fixed stand in this paper. The results of our testing are presented.

Key words: Photovoltaics, solar energy, power plant

INTRODUCTION

In recent years in the Czech Republic as well as in a number of other states electric power produced in photovoltaic (PV) power plants is financially subsided. This is why a high number of photovoltaic power plants have been built. In Germany the development of photovoltaics was even more marked and they adopted the policy of subsidies already several years earlier. In the years 2006-2008 several photovoltaic power plants with the peak output higher than 1 MW_p have been put into operation in the Czech Republic. The record installation changed very rapidly. In the years 2009-2010 the number of installation was much larger. Table 1 shows increasing of the total installed PV power in the Czech Republic during the years 2006-2011 and Table 2 shows few examples of the largest PV installations. Since the year 2011 the subsidy is very limited.

We constructed and tested few PV power plants in the Czech Republic during last years. We will present our results of the data collecting and their comparison in this paper.

Table 1. Increasing of the total installed PV power in the Czech republic

Date	installed PV power (MW_p)
1st January 2006	0.15
1st January 2007	0.35
1st January 2008	3.4
1st January 2009	65.7
1st January 2010	463
1st January 2011	1400

MATERIALS and METHODS

Fig. 1 shows the location of few compared PV power plants in the Czech Republic. The isoareas of the average annual solar energy incident in the Czech Republic on the area with the slope corresponding with the latitude are shown as well, the isoareas were published in the internet pages of the Czech Hydrometeorological Institute (2010). In these power plants, the PV panels based on the crystalline silicon have been used. The panels have been oriented to the south, the inclination is 35°. Only the PV system in Prague is described down in details. The installed peak power in kW_p is shown in the Table 3. For example, Fig. 2 presents the power plant Bušanovice.

The PV system in Prague has following construction. There are two parts of the small experimental PV system and they have been built so that three PV panels of Chinese manufacturing with the rated output P_{max} = 170 W_p and with the efficiency of the photovoltaic energy conversion η = 16 % have been installed on a fixed stand which is oriented to the south. In the first part the stand has a fixed inclination of 35°, in the second one the stand has an adjustable inclination of 35°during the summer period and 45° during the winter period. The three panels are connected in series and connected to a German inverter of the brand Sunny Boy, type SB 700, installed in the laboratory. Via this inverter the PV systems are directly connected to the grid of standard AC voltage of 230 V. The data are simultaneously stored by a data logger on a memory card and, after login, the data are monitored in real time by a server. The connection is accomplished using cables and water-proof connectors of the company Tyco. The view of both PV systems in winter period is presented in Fig. 3. Each part of the PV system has thus the peak output power of 0.51 kW_p and the year-round monitoring of data started in March 2009. Karimov, Abid (2010) presented a similar construction.

Table 2. Examples of the largest PV power plants opened in the Czech Republic during the years 2006-2010

location	maximum power (MW_p)	year of opening
Opatov	0.06	2006
Bušanovice near Volyně I	0.66	2006
Dubňany in Hodonín region	0.515	2007
Ostrožská Lhota near Uherské Hradiště I	0.702	2007
Úštěk - Habřiny in Litoměřice region	0.507	2007
Bušanovice near Volyně II (PV system extended)	1.36 in total	2008
Jaroslavice near Znojmo	0.9	2008
Ostrožská Lhota II (PV system extended)	1.622 in total	2008
Dubňany in Hodonín region (PV system extended)	2.1 in total	2008
Hodonice near Znojmo	2.15	2009
Moravský Krumlov (tracking stands with ridge radiation concentrators)	0.432	2009
Žešov near Prostějov	0.604	2009
Sudoměřice in Hodonín region	3.5	2009
Nová Ves in Mělník region	35.1	2010
Ševětín in České Budějovice region	29.9	2010
Vranovská Ves in Znojmo region	24,2	2010
Veselí over Morava	17	2010

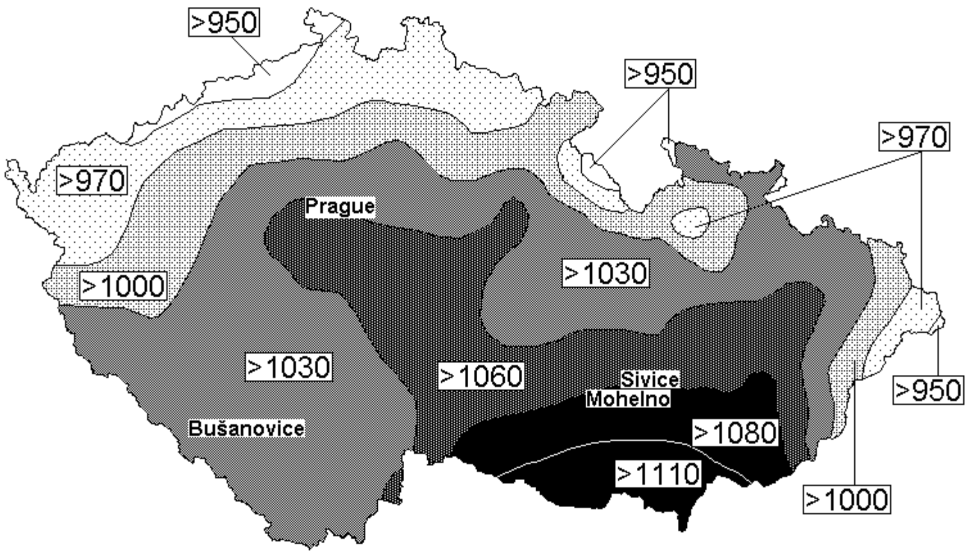

Figure 1. The isoareas of the average annual solar energy incident in the Czech Republic on the area with the slope corresponding with the latitude and the location of compared PV power plants

Figure 2. The PV power plant Bušanovice

Figure 3. The PV system Prague (CULS Prague)

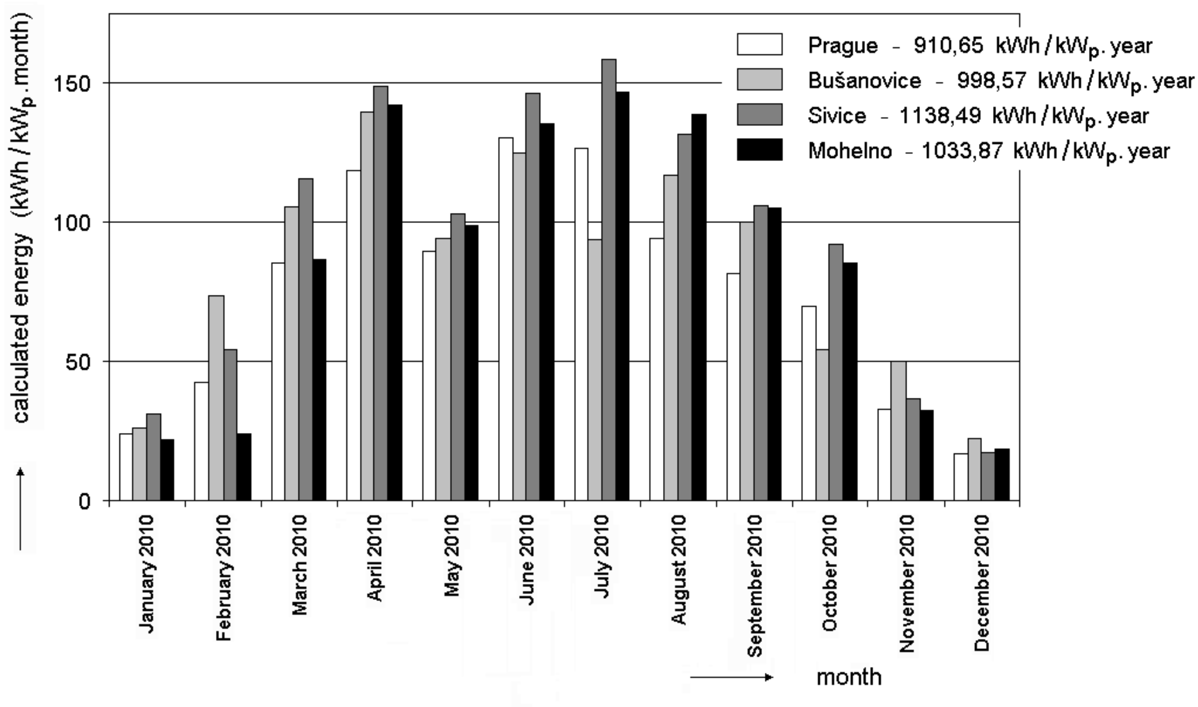

Figure 4. Comparison of the produced amount of electric energy in the tested PV power plants with fixed stands in the Czech Republic

RESULTS and DISCUSSION

The systematic measurement and the comparison of the produced amount of electric energy in the above mentioned photovoltaic power plants with fixed stands is given in Fig. 4. The produced amount of the electric energy during the year 2010 is in the Table 3. The calculation of the energy in kWh/kW$_p$ is shown as well. This finding is in agreement with the annual values expected in the Czech Republic and it corresponds with the isoareas in the Fig. 1. There were more rainy days in the central Europe during the May 2010 and that is the reason, that the energy amount is lower. The power plant Mohelno is not far from the nuclear power plant Dukovany. It is possible, that there is higher concentration of the water vapour from the cooling towers in the atmosphere. In this case would be higher the absorption in the near infrared region and it could be the reason, that the amount of the produced electric energy is lower than in Sivice.

Table 3. Comparison of the amount of produced electric energy in few PV systems with fixed stand constructed and tested in the Czech Republic

the year 2010	Prague fixed inclination 0.51 kW_p el. energy production (KWh)	Prague fixed inclination 0.51 kW_p el. energy calculation (KWh/kW_p)	Prague adjustable inclination 0.51 kW_p el. energy production (KWh)	Prague adjustable inclination 0.51 kW_p el. energy calculation (KWh/kW_p)	Bušanovice 660 kW_p el. energy production (KWh)	Bušanovice 660 kW_p el. energy calculation (KWh/kW_p)	Sivice 11.22 kW_p el. energy production (KWh)	Sivice 11.22 kW_p el. energy calculation (KWh/kW_p)	Mohelno 1500 kW_p el. energy production (KWh)	Mohelno 1500 kW_p el. energy calculation (KWh/kW_p)
January	12.12	23.76	14.36	28.16	17262	26.15	348.70	31.08	32501	21.67
February	21.64	42.43	22.66	44.43	48440	73.39	607.50	54.14	35682	23.79
March	43.32	84.94	44.61	87.47	69626	105.49	1292.90	115.23	129961	86.64
April	60.34	118.31	60.85	119.31	91884	139.22	1668.20	148.68	212839	141.89
May	45.76	89.73	45.03	88.29	62087	94.07	1152.80	102.75	147487	98.32
June	66.24	129.88	65.28	128.00	82309	124.71	1637.80	145.97	203102	135.40
July	64.55	126.57	63.71	124.92	61850	93.71	1777.40	158.41	219807	146.54
August	48.00	94.12	48.02	94.16	76839	116.42	1470.31	131.04	207814	138.54
September	41.63	81.63	42.19	82.73	65548	99.32	1189.97	106.06	157620	105.08
October	35.62	69.84	38.52	75.53	35821	54.27	1029.55	91.76	127549	85.03
November	16.72	32.78	19.90	39.02	32768	49.65	405.60	36.15	48786	32.52
December	8.49	16.65	11.03	21.63	14620	22.15	193.10	17.21	27657	18.44
in total		910.6		933.6		998.6		1138.5		1033.9

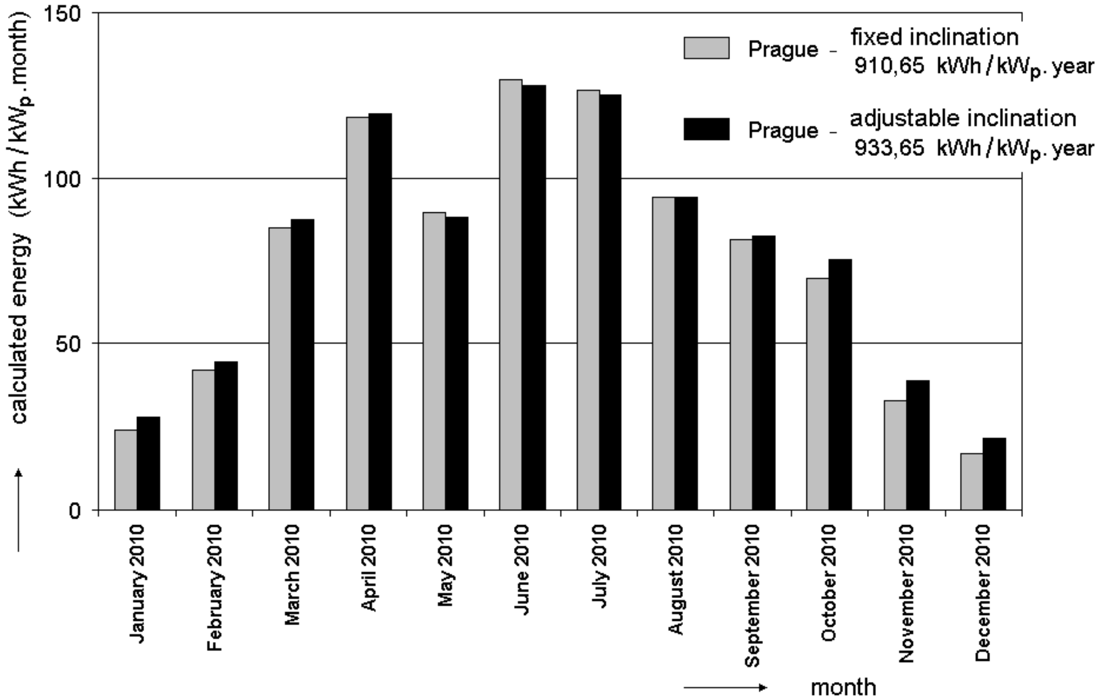

Figure 5. Comparison of the produced amount of electric energy in the tested PV systems with fixed and adjustable inclination of PV panels in Prague

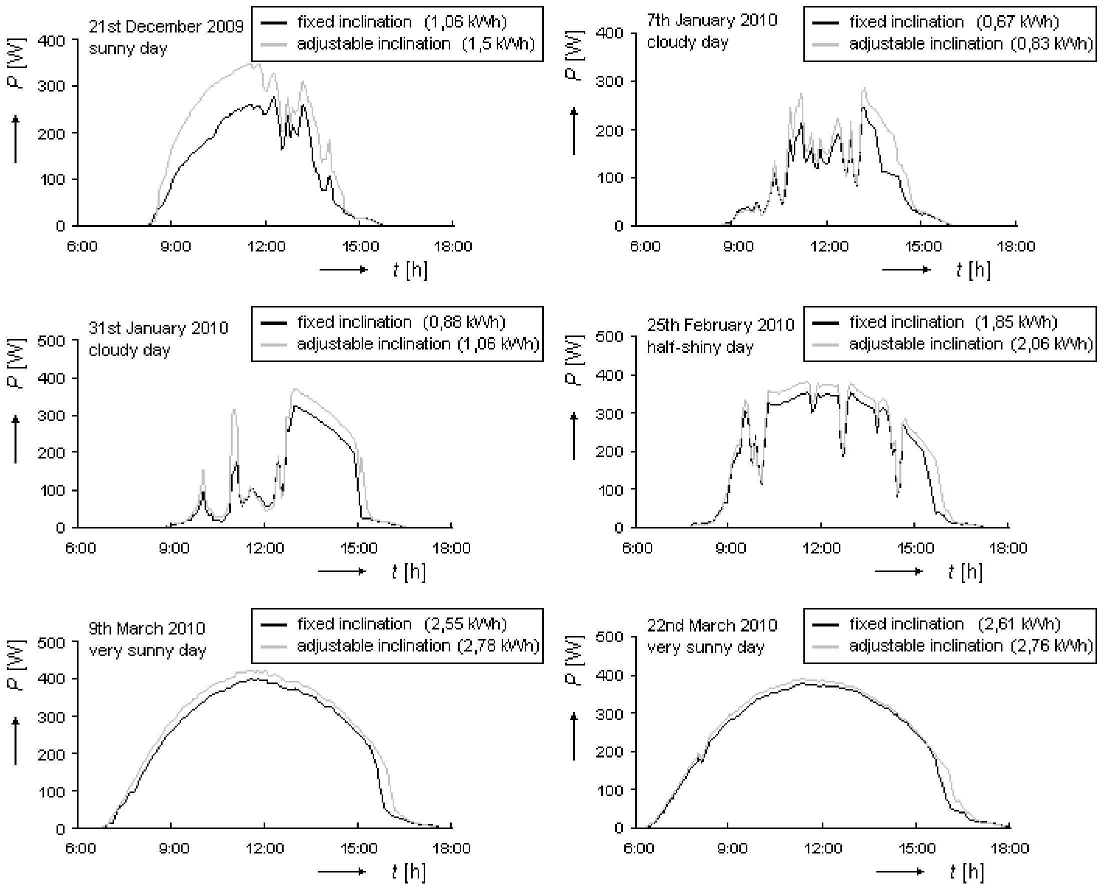

Figure 6. Examples of the dependence of the instantaneous output power on the time during selected days of the monitored period with different inclination of panels

Fig. 5 shows the comparison of the PV systems at the Czech University of Life Sciences Prague with fixed and adjustable inclination. During this annual monitoring period the amount of produced electric energy was $W = 464.4$ kWh/year in the system with fixed inclination and $W = 476.2$ kWh/year in the system with adjustable inclination. The calculated value of annual production of electric energy per 1 kW_p of installed PV panels is $W_p = 910.6$ kWh/kW_p.year in the PV system with fixed inclination and $W_p = 933.6$ kWh/kW_p.year in the PV system with adjustable inclination. During the summer sunny days the maximum values of the incident radiation intensity moderately exceeded the value of 1000 $W.m^{-2}$.

These values correspond to the values expected in Prague at the 50° of north latitude. If the PV panel inclination is not adjusted during the year, the inclination of 35° is optimal for the maximum annual production of the electric energy. This inclination corresponds to the operation in the summer period as thus maximum amount of electric power is produced. It is evident that the adjustment of a higher inclination in the winter period increased the total annual amount of produced electric energy by about 2.5 %. It is possible that with a more frequent adjustment of the inclination the amount of produced energy could be a little higher but the difference would not be very important. Fig. 6 presents examples of the dependence of the instantaneous output power on the time during selected days of the monitored period with different inclination of panels. For comparison also the values of produced electric energy in the respective day are presented, they are corresponding to the area under the graph because

$$W = \int_{\Delta t} P \, \mathrm{d}t \,, \qquad (1)$$

P is the power and t is the time.

CONCLUSION

Our endeavor was aimed to the construction and realization of photovoltaic power plants with fixed stands and a comparison of the fixed and adjustable inclination of PV panels from the point of view of the amount of produced electric energy during one year. The photovoltaic systems were installed in the Czech Republic, the obtained values correspond to the assumption and they are also in relation with the values of larger PV power plants in the Czech Republic.

From the measured and evaluated data it can be seen that the adjustment of the PV panel inclination during the year can enhance the amount of produced electric energy maximum by several per cents. Therefore, it has some sense if the PV system is well accessible and the adjustment of the inclination makes no problems. If the adjustment would cause problems, it depends on the consideration of the operator whether the adjustment of the inclination during the year will pay off.

More information can be found, for instance, in the book Libra, Poulek (2010) or in the internet pages Poulek Solar, Ltd. (2011).

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