# INFLUENCE OF THE RES ON LONG TERM DYNAMICS IN POWER SYSTEM

Michal KOLCUN, Pavol HOCKO, Matúš NOVÁK
Department of Electrical Power Engineering, Faculty of Electrical Engineering and Informatics,
Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic, tel. +421 55 602 3550,
e-mail: michal.kolcun@tuke.

**ABSTRACT**

*This paper discuss about long-term dynamics in simplified model of the power grid. This model represents Slovak power system connected trough inter-tie line to interconnected power system – ENTSO-E. The Slovak power system itself is represented by node SEPS. To this node conventional and renewable energy sources are connected. The significant growth of installed power capacity of renewable energy sources (RES) in the last few years may cause incidental disturbance of power balance in the power system. This problem is typical for photovoltaic power stations. It is very hard to predict photovoltaic (PV) power production especially during cloudy weather conditions. Because of this fact it is very important to determine maximum share of RES in each power system. This paper deals with impact of PV in power system.*

**Keywords:** *renewable energy sources, long-term dynamics, photovoltaic, power system operator, power system, ENTSO-E*

## 1. INTRODUCTION

Until the 30$^{th}$ of June 2011 there were 857 producers of electricity from photovoltaic in Slovakia. This date is also associated with the end of state's energy purchase price support. The 33 of 857 photovoltaic power plants (PVPP) has installed capacity more than 1 MW. All PVPP are connected to distribution power subsystem. This means that the power system operator can't controls power production from this sources. All produced energy from RES must be delivered to the power system. However, power system operator (PSO) is required to maintain power system balance and cross-border power balance with other power systems. In this case there is unknown value of power consumption and also unknown power production from RES.

Pursuant to European Union Slovak Republic has to guarantee 14 per cent share of power production from RES of total power consumption in year 2020. In year 2010 advantaged prices of electricity from RES caused more than 18 per cent power production share from RES on total power consumption. Table 1 shows power production share from RES of total power consumption in the period from year 2007 to 2010.

The RES can be divided by type of primary energy source to power production from water, sun, wind, geothermal, biomass and biogas energy. Some of these renewable sources can be in some specific circumstances unpredictable. This phenomenon is most pronounced in energy from sun and wind. Because of the weather conditions photovoltaic and wind power plants may by in some cases highly unpredictable. Installed power of wind power plants in Slovakia is only 3.14 MW. This capacity is negligible and can't influence power balance.

Installed power in PVPP is more than 480 MW. With the 7100 MW of total installed power capacity in Slovak power system, this share is significant and in some cases may greatly influence power system balance. This may occurs instability especially in summer, when share of power production from PVPP is the largest in the year. Alternately cloudiness causes significant decrease of delivered power from PVPP in the range of tens of percent. The large share of produced power from RES can thus causes instability in the power system.

**Table 1** Growth of RES share of total power consumption

| *Year* | *2007* | *2008* | *2009* | *2010* |
|---|---|---|---|---|
| ***Power production from RES (GWh)*** | *5080* | *5147* | *5173* | *5280* |
| ***Total power consumption (GWh)*** | *29717* | *29824* | *27467* | *28761* |
| ***RES power production share (%)*** | *17,1* | *17,3* | *18,8* | *18,4* |

## 2. SUBJECT

The value of cross-border power balance was in year 2010 between 100 and 300 GWh. This value depends mainly on period of year. This situation occurred due to Bohunice nuclear power plant shutdown and also because the general reduction of consumption of electricity due to depression. The progress of cross-border power balance in year 2010 is showed on figure 1. The difference between consumption and production of electricity was in year 2010 more than 1000 GWh in import.

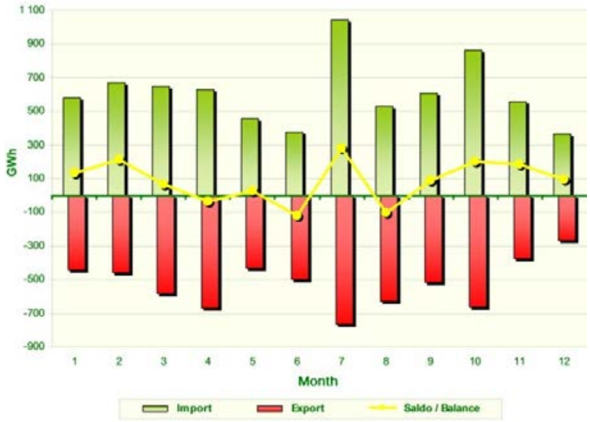


**Fig. 1** Progress of cross-border power balance in 2010

## 3. MODEL SIMULATION METHODS

Figure 2 shows simplified model of Slovak power system. This model was inspired by the Czech power system model made by Mr. Ing. Karel Máslo, CSc. This model includes simplified power system of Slovak Republic (PS SR) connected to interconnected power system – ENTOS-E. ENTSO-E is modeled as individual control area (marked as green area).This part includes the data on the measuring method and instruments as well as experimental results.

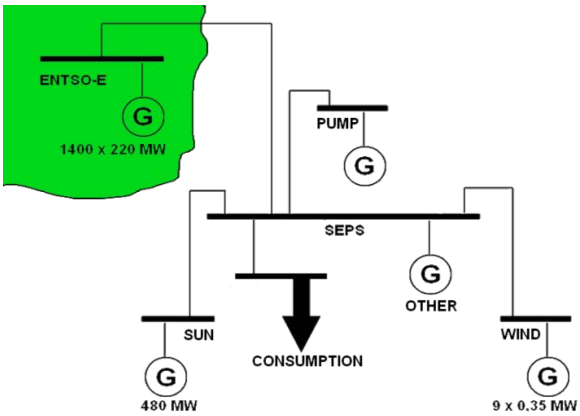


**Fig. 2** Modelled scheme

All sources type are connected to the node SEPS through power lines. Node CONSUMPTION represents the power system load. Figure 3 compares daily load diagram curve in two cases. First is the year's maximum load (red curve) second is the year's minimum load (blue curve). Results are from year 2010. Year's minimum load is in august when power production from PVPP is maximum, thus the power production is maximum. From figure we can estimate that PV share on total load is about 20%.

The average summer day load was chosen as daily load dynamics in modeled scheme. Thus, modeled situation has general dynamic characteristics during summer day in 2010.

All conventional sources (thermal and nuclear power plants) are connected directly to the node SEPS. Number of power generators and power range of the generators are equivalent to real values. Dynamics model of this node is from [1] and [6].

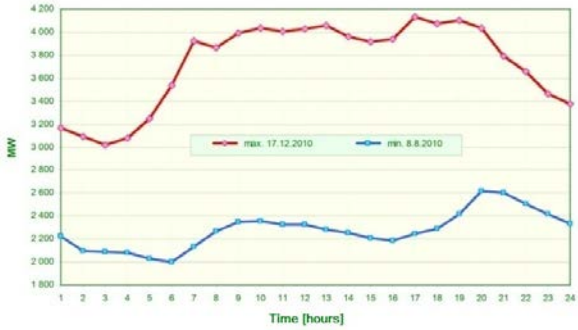


**Fig. 3** Daily load diagram with minimum and maximum year's load

### 3.1. Nodes description

The node ENTSO-E represents the interconnected power system ENTSO-E and it is modelled as one block of 1400 generators each with 200 MW installed power. In terms of dynamic this node represents power system with constant voltage [1].

The node WIND represents wind power plants which are connected to the power system. Total installed capacity in wind turbines is in Slovakia only 3.14 MW. Wind turbines are part of model but can be negligibled. Table 2 shows all nodes with their preferences and comments.

**Table 2** Nodes used in model

| *Node name* | *Load [MW]* | *Installed Power [MW]* | *Comment* |
|---|---|---|---|
| *WIND* | *0* | *9 x 0,35* | *Wind Turbines* |
| *SUN* | *0* | *480* | *Photovoltaic Power plants* |
| *PUMP* | *0* | *1020* | *Pump storage Power plants* |
| *SEPS* | *0* | *7100* | *Slovak Power System equivalent* |
| *CONSUMPTION* | *2700* | *0* | *Power system load according to daily load curve* |
| *ENTSO-E* | *5000* | *1400 x 220* | *Equivalent of ENTSO-E power system* |

The PVPP which delivers power to power system are in model connected to the node SUN. As has been said total installed power capacity in PV is set to 480 MW which is equivalent to real value. PV was in programme MODES modelled as PMGC (permanent magnet generator and frequency converter) generator. Power source model was set to SUNS which is model determined for photovoltaic panels. During long–term dynamic simulation different parameters of this model was used. These different parameters represent different weather conditions. All used models are described in [3], [4], [5] and [7].

### 3.2. Tertiary regulation

Pump storage water power plants which are connected to tertiary real power regulation are connected to the node PUMP. Power production of Cierny Vah, Liptovska Mara and Ruzin pump storage power plants are shown on figure 4. Power stations are deployed in time of maximum power consumption peaks during the day. Their task is to maintain power balance in power system during time when the consumption reaches the maximum values. These pump storage power plants are connected to the tertiary active power control. Production of these power plants was selected directly to this specific situation in this simulation to maintain power balance and to minimize the central controller output value which will be mentioned later in this paper.

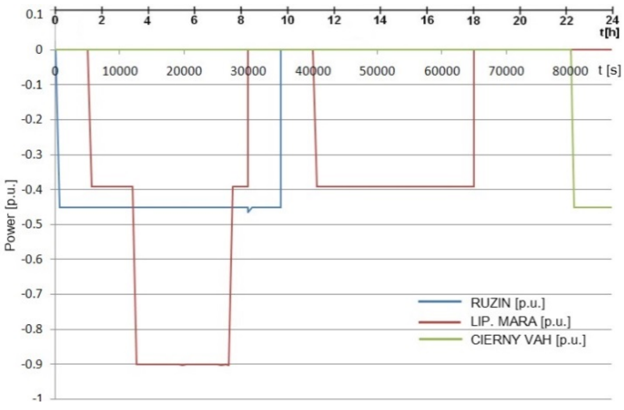


**Fig. 4** Pump storage power plant production during one day.

## 4. LONG-TERM DYNAMIC SIMULATION

The influence of PVPP to long-term dynamics is modelled in programme MODES. Dynamic simulation time is set to 24 hours (86400 seconds). Sampling period was set to 600 seconds.

The case follows from planned cross-border power balance which is set to 100 MW. Central controller maintains nominal frequency value and planned cross-border balance value. Output results from MODES are graphically showed in following figures.

Whole simulation is divided to two main cases.

- Case 1 – sunny day
- Case 2 – cloudy day

In the first case sunny summer weather is simulated during whole day (24h). Thus this delivered energy from PVPP depends only on the intensity and terminal angle of solar radiation. This case represents blue curve. In second case the cloudy summer weather is modelled. This case represents the cloudy weather when clouds are crossing the sun and causes power delivery deviations in PVPP. This case represents red curve. Results are for comparison shown in figure 5.

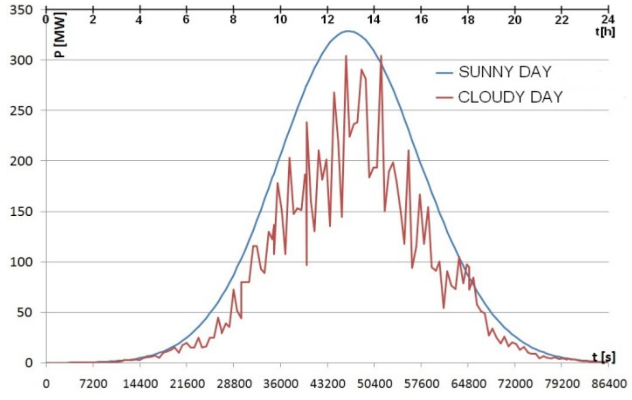


**Fig. 5** Power delivered from PV power plants

We can see sharp deviations of delivered power from PVPP caused by clouds during the cloudy weather conditions. These deviations are significant and in some cases during the day reach value of 150 MW. This phenomenon occurs during the peak of daily load. These significant power deviations may in some cases cause power system instability. The deviation is also shown in central controller output (Figure 6). Figure 6 compares central controller regulation process in Slovak power system. The controller maintains system frequency and cross-border balance values. During the sunny day the controller regulation process (showed as blue curve) has smaller deviations which mean smaller regulation power and more stable operation of power system. During the cloudy weather the controller's output deviations are more significant and sharper. This is caused by clouds which decrease the solar radiation and thus decrease the power produced by PV power plants. All these power deviations in power system have to be offset by another energy sources.

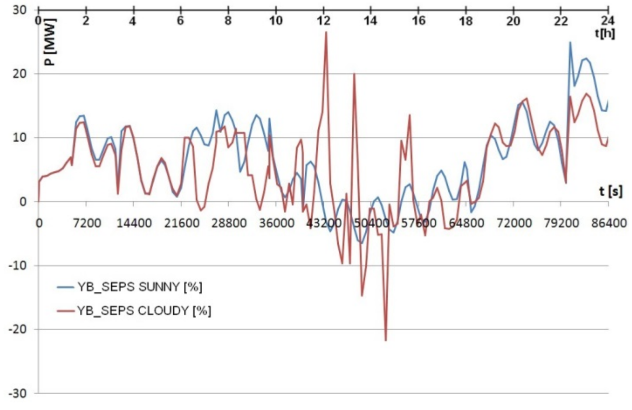


**Fig. 6** Central controller output

Figure 7 compares cross-border balance planned value which is set to 100 MW (showed as black line) with real power transmitted trough inter tie line during sunny (blue curve) and cloudy (red curve) weather conditions.

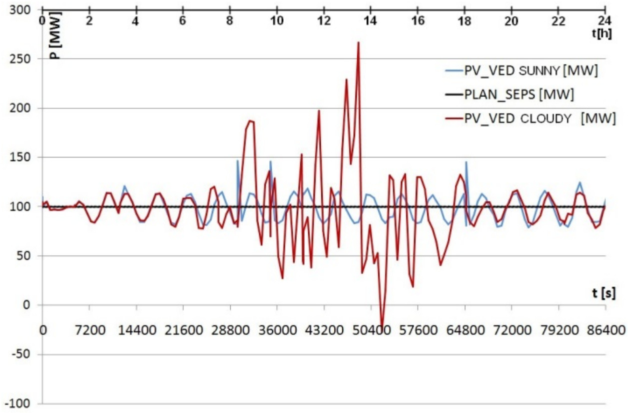


**Fig. 7** Cross-border balance value for both cases

Both curves are until time circa 30 000 seconds (about 8 hours) very similar. At time circa 40 000 cloudy weather causes fast and significant changes in PVPP power production. This changes causes big deviations in power transmitted trough inter tie line. As figure shows, power deviations during cloudy weather can be more than 150 MW compared with planned value.

Secondary active power control is set to maintain power balance in controlled area (modelled scheme excluded ENTSO-E node). Power balance is disturbed by PV power plants production deviations during the day. Power delivered from selected power plants connected to the secondary regulation process is showed in figure 8. Central controller controls power delivery from power plants to maintain frequency and power balance to set values.

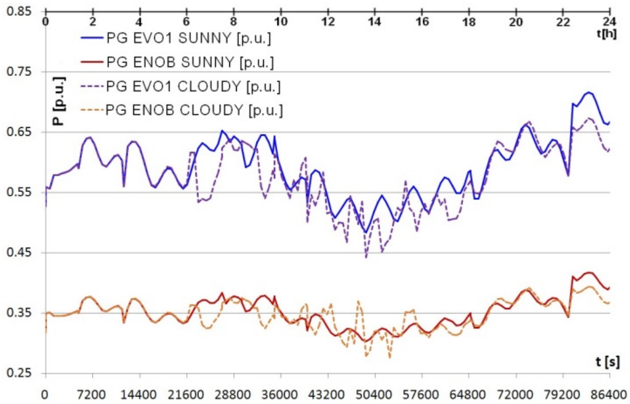


**Fig. 8** The secondary regulation process on selected power plants for both cases

Blue curves (solid and dashed lines) show active power delivered from power plant Vojany (EVO1). The dashed curve shows power delivery for cloudy weather. Orange curves represent power delivered from power plant Novaky (ENO B) where dashed line represents delivered power for cloudy weather and solid line is for sunny weather.

As was mentioned the power balance maintain is ensured by pump storage power plants which are connected to the tertiary regulation process. These power plants deliver or consume power to compensate the deviation between power production and consumption in power system. This deviation is in bad weather conditions caused mainly by PVPP (as was shown in Fig. 5).

Figure 9 shows power delivered from PVPP together with central controller output deviation for both cases. This figure compares differences between sunny and cloudy day and shows impact of PVPP connected to the power system with big share of RES.

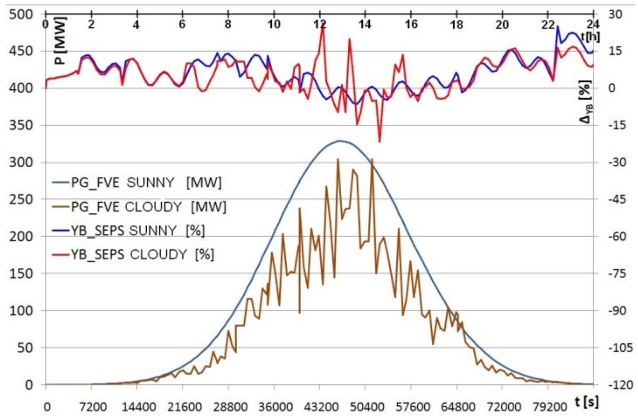


**Fig. 9** Central controller deviation and PVPP power production

## 5. CONCLUSIONS

Paper describes influence of RES on long-term dynamics in Slovak power system. The 24 hours simulation shows power production of RES especially PV power plants during the two different weather conditions. These simulations show that the influence of RES during the average summer day when the share of power production from RES in power system is the largest is very significant. This large share may during bad weather conditions causes large power balance deviations, changes in cross-border balance and in some specific cases instability in power system. This state is caused by significant growth of RES in Slovak power system. If this trend will continue, the unpredictable sources connected to the power system may cause bigger deviations or instability in power system.

RES was in programme MODES modelled as one central power source with 480 MW of total installed power. This source represents all PVPP which are connected to the power system in Slovakia in 2010. This paper refers the influence of RES as unpredictable power source on power.

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## BIOGRAPHIES

**Michal KOLCUN** was born in 1954 in Ruska Vola nad Popradom. In 1979 he graduated at the Faculty of Electric Power Engineering of the Moscow Power Engineering Institute. In 1989 he defended his PhD on the same institute in Moscow. In 1993 he habilitated to associated professor at the department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. In 2000 he inaugurate to professor, in the field of Power Engineering and Energetic, at the Faculty of Electrical Engineering and Informatics at Technical University in Košice. Since 2006 he is honorary professor at ÓBUDA University in Budapest, Hungary. Since June, 2012 he is Doctor Honoris Causa from Politechnika Czestochowa, Poland. Since 1979 he is working at the Department of Electric Power Engineering on the Faculty of Electrical Engineering and Informatics at Technical University in Košice. His scientific research is focusing on a power system control and computer application in electric power engineering. In addition, he also gives lectures in multiple foreign universities in Moscow, Sankt Peterburg, Czestochowa, Zelona Gorza, Budapest, Riga, Tallinn, Varna, Prague, Ostrava and Barcelona.

**Pavol HOCKO** was born on 25.8.1985 in Prešov. He graduated with distinction in 2010 at the department of Electric Power Engineering of the Faculty of Electrical Engineering and Informatics at Technical University in Košice. Since 2010 he is on PhD study. His scientific research is focusing on power system control and renewable sources optimization.

**Matúš Novák** was born on 27.7.1987 in Prešov. In 2011 he graduated (MSc) with distinction at the department of Electric Power Engineering of the Faculty of Electrical Engineering and Informatics at Technical University of Košice. Now he is PhD. Student at the same department. His scientific research is focused on Power System Stability.