doi: 10.7250/pee.2014.004
2014/32

Impact of Renewable Energy Sources on Power System Stability

Zsolt Čonka[1], Michal Kolcun[2], György Morva[3],
[1–2] *Technical University of Košice*, [3] *Óbuda University Budapest*

***Abstract* – This paper discuses the influence of the renewable energy sources to the islanding operation of the power system. Constantly increasing number of renewable energy resources such as photovoltaic and wind power plant has a significant impact on the stability of electricity transmission. In this article there are three different scenarios considered. Scenarios were made according to photovoltaic (PV) development outlook documents listed in references. The simulation was made in MODES on the Slovak power system model.**

***Keywords* – Photovoltaic, influence, power system stability, MODES, island operation.**

I. Introduction

One of the major factors entering the development of PS of Slovak Republic is the construction of new renewable energy sources, especially photovoltaic and obligation to buy all of the produced energy from these sources in real time. This places increased demands on support services and regulatory power. Installed capacity of photovoltaic power plants in Slovakia has a value of 524 MW. The value of PV boom continues to grow. High representation of electricity generation from PV consumption in the system may under adverse weather conditions (cloud crossing over PV power plant, causing significant power fluctuations and consequently a system frequency) cause significant distortion power balance, leading to significant changes in the balance due to the activation of primary power control PPC [1], [2], [3].

In this paper we modelled the impact of the PV system during islanding operation. During island operation block turbine controller block is switched to speed control. In this case, islanding operation is modelled throughout regulatory region (RR). Therefore, the power control of unit is left in the frequency regulation. The network is modified so that it is possible to model the independent operation of RR SVK and the rest of the UCTE network, is represent by equivalent blocks. The objective is to evaluate the function of support services for increased demands for regulation, which represents as island operation of SVK power system. Quality rating PPS is evaluated for all modelled scenarios for clear and cloudy day.

II. Modelled Power System

For modelling purposes islanding operation of SR interconnected system were modelled net additions in each regulatory region as equivalent nodes representing the load on the regulatory region and the equivalent blocks representing the production of the regulatory region. Load of nodes surrounding regulatory region remained is unchanged. Installed capacity equivalent block EKVIVU equivalent and load of the node was adjusted so that the total installed capacity and load on network modelling remained unchanged and were consistent with the parameters of the modelled system. List of equivalent blocks and load nodes in each regulatory region is in Table. 1.

TABLE 1

Equivalent Blocks and Load Nodes Added to the Network Model

Block	Node	S_n, MVA	N_{tmin}, MW	N_{tmax}, MW	P_{odb}, MW	P_{dod}, MW
CZ	CZ	12 300	0	10 500	7 200	7 200
HU	HU	6 505	0	5 000	4 600	4 600
UA	UA	2 585	0	2 200	850	850
PL	PL	22 100	0	18 800	15 500	15 500
AT	AT	9 900	0	7 900	7 700	7 700

Equivalent units are only involved in the primary power control PPC and represent an installed capacity of regulatory region in which they work [7].

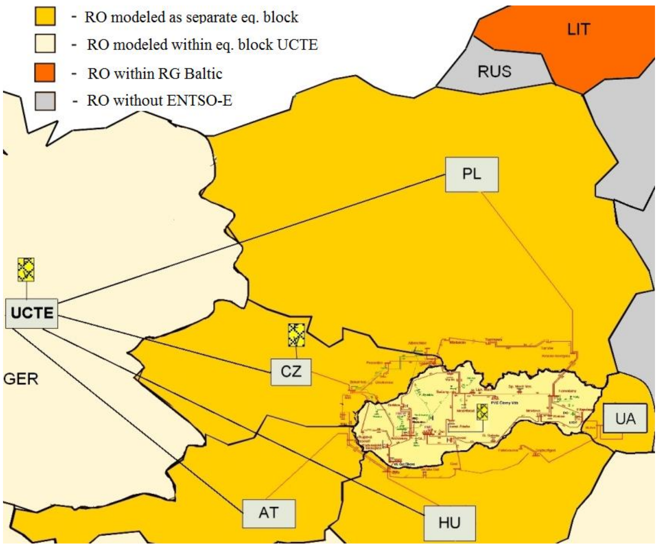

Fig. 1. Modelled network on a geographical map of the Europe.

Figure 1 is a diagram of the modelled system that is at the geographical map of the EU with highlighted regulatory regions which are modelled within the equivalent node EKVIVU and separate equivalent nodes of surrounding regulatory regions. Grey rectangles represent equivalent units which operate according to Table 1 [4], [5], [6].

III. Islanding Operation

Islanding operation was modelled for all three variants (see Table 2, Table 3 and Table 4).

TABLE 2

SCENARIOS WITH PARAMETER OF EQUIVALENT BLOCK EKVIVU

Parameter	Reference scenario	High scenario
P_N, MW	899 517	1 168 000
$Nf_{MIN} - Nf_{MAX}$, %	−1.5 – 1.5	−1.5 – 1.5
P_{PRV}, MW	± 10 800	± 14 100
k_{COR}, –	2	2
λ, MW/Hz	28 800	44 000

TABLE 3

SCENARIOS OF INSTALLED CAPACITY OF PV IN EACH MODELED RR

Reg. region	Ekv. Blok	Present status, MW	Reference scenario, MW	High scenario, MW
Belgium	FV_BE	2 650	3 440	7 000
Czech rep.	FV_CZ	2 072	2 400	4 000
France	FV_FR	4 003	5 400	30 000
Germany	FV_DE	32 411	39 500	80 000
Greece	FV_GR	1 536	3 400	8 000
Italy	FV_IT	16 361	26 090	42 000
Slovakia	FV_SVK	517	1 040	3 000
Spain	FV_ES	5 166	18 620	18 000
U.K.	FV_UK	1 829	8 000	22 000
EU27Oth	FV_RES	3 498	26 690	35 350
SUM EU27		**70 043**	**134 580**	**249 350**

where:

EU27Oth – RR representing the other countries belonging to EU27, where PV installed capacity is less

TABLE 4

SHARES OF PRODUCTION OF PV FOR EACH VARIANTS

Scenario	p_{FVEMAX}, %	p_{FVEINT}, %	p_{EFVE}, %
Present status 2013	8.7	7.7	2.91
Reference 2020	12.74	11.4	4.29
High 2020	23.78	21.2	8.03

Islanding operation is forced by scenario of gradual disconnection of individual profiles. Under a scenario occurs in time 1:00 am will disconnect congested profile SVK-PL. Subsequently, at the time, 2:10 am will disconnect profile SVK-CZ. After switching off the two most loaded sections, the value of Slovak interconnection is zero (sum of all transmitted power profiles) (Fig. 2 – change of the entered value of balance). RR is ready for the formation of the island, and profile changes to zero avoiding large power jump differences during formation of the island and subsequent instability of the system. At the time of 5:30 after turning off the last profile with Ukraine passes RR SVK to island operation. Control blocks involved in PPC operates in the frequency mode. The system has different frequency as the rest of the interconnected system. Value balance is zero. The island blocks must compensate the load change in the system during the day (DDL) and the increase in production of PV.

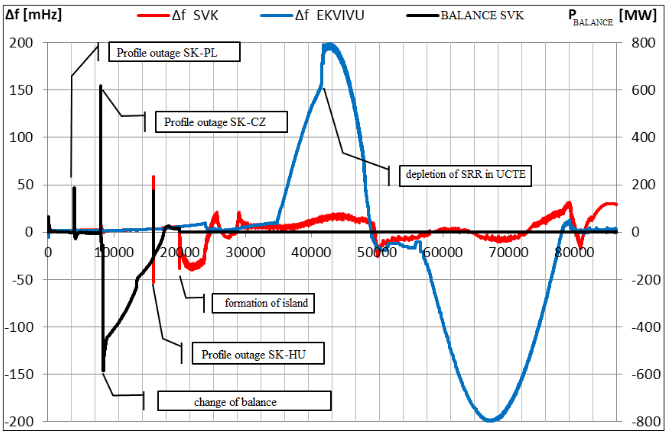

Fig. 2. Progress of frequency offset and balances to give the island RR. SVK scenario – sunny.

Transition cloud has a major impact on the frequency offset in the system. During islanding operation RR SVK is due to a lower proportion of PV electricity production is the frequency deviation lower than that of the UCTE Deviation progress of balance and frequency balance for the first scenario for a cloudy day is in Fig. 3.

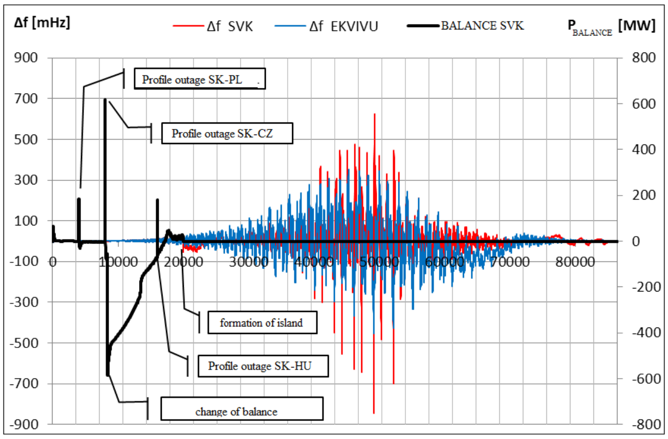

Fig. 3. Progress of frequency offset and balances to give the island RR. SVK scenario – Cloudy.

In the case of a cloudy day, the cloud transition occurs due to variations in electricity production from photovoltaic power plants and thus to the power deficit in the system, which is ultimately reflected as a change in frequency and balance. In the case of a cloudy day the production of PV is not so high and there is no depletion of the units involved in the secondary regulation reserve SRR. Transition of clouds so causes significant variations in the frequency of the system, but these are temporary and do not cause significant instability in the system. Cloudy day puts higher demands on ancillary services, but does not cause instability in the system. FVE are equipped with under frequency protection which disconnects the PV system if the frequency deviation exceeds the Δ*f*MAX = 1.5 Hz, or Δ*f*MIN = 2.5 Hz. This protection is used as the final step in reducing the frequency of the system for the surplus power and over-frequency. Power system working in island operation has in case of modelling of the first two scenarios paradoxically lower frequency deviation compared to the rest of the system. This fact is caused by relatively small proportion of PV electricity production compared to the rest of the UCTE.

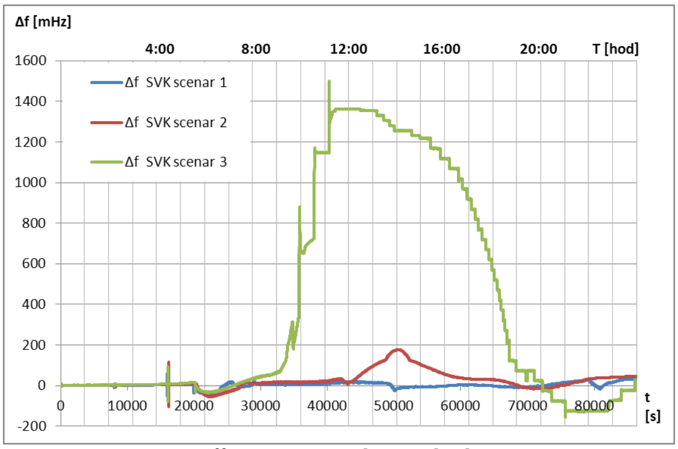

Fig. 4. Frequency offset in RR SVK during island operation – sunny.

Islanding operation was modelled for all three scenarios projected prognosis of PV. Comparison of variation in frequency islanding RO SVK in individual cases is in Fig. 4. For the third scenario, which assumes the highest proportion of PV consumption (PFVE = 3 000 MWp) is the frequency significantly higher (Fig. 4). Frequency deviation is maintained through modelling tertiary regulation reserve TRR automatics. In reducing the frequency deviation is as first deployed PVE Čierny Váh in the pump operation, subsequently then TRR lowered the power of large blocks or their switch them off. The final step is to increase the load in selected load nodes (USSK Slovnaft). Under the conditions mentioned above is a system in island operation maintained in a stable running with a maximum deviation frequency ΔfMAX3 = 1 483 mHz. In the case of modelling a cloudy day frequency deviation in RR SVK during island operation, the frequency deviation is significantly higher in the first two modelled scenarios. These changes, however, are short and do not significantly affect the stability of the system. The gradual increase in the supply of power from the PV during the day is compensated by SRR. In the scenario with the highest proportion of PV the situation is different. Increase the supply of power from the PV plant will compensate by the SRR, which in addition to fluctuations in the frequency deviation caused by passing clouds turning off the central controller P / f. The turn off secondary regulation of RR SVK occurs at the time of 29,240 seconds (8:07:20 pm) (Fig. 5 – switch off P / f). Deactivation of the secondary power control in the system will cause a deficit of performance.

Under the influence of low speed of machines all the blocks are gradually switched off in the modelled system SVK and blackout occurs.

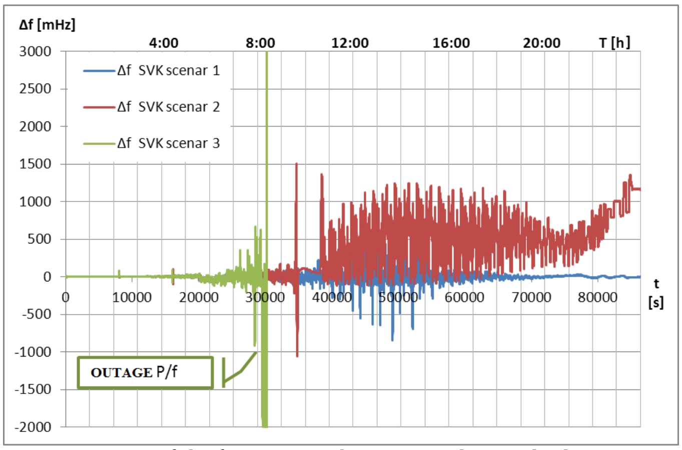

Fig. 5. Deviation of the frequency in the RR SVK during island operation – Cloudy.

IV. Conclusion

The aim of modelling island operation of RR SVK is to analyze the impact of proportion of PV for different scenarios on stability provided that the distortion of power balance in the system by PV production will not be compensated instantly by changing of supply balance (activation PPC in interconnected system).

Blocks in modelled RR in this case compensate the supply of PV connected to the same RR, but despite this fact occurred in the case of the highest scenario to instability and collapse of the system. In the case of modelling a clear day had to be deployed all means to compensate for the supply of power from the PV. In the case of moving cloud occurs by influence of over-frequency switching off the secondary regulation followed by blackout. On the other hand, it should be kept in mind the fact that the formation of blackout occurred when the traffic across the island model assuming RR increased supply of PV and the fact that none of PV was weaned. But the aim was to show how it may be significant impact on the stability of the power system.

Acknowledgements

This work was supported by Slovak Research Agency No. VEGA 1/0388/13 project.

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Michal Kolcun was born in 1954 in Ruska Vola nad Popradom, Slovakia. In 1979 he graduated from the Faculty of Electric Power Engineering of the Moscow Power Engineering Institute. In 1989 he defended his PhD at 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, his thesis title was High-tension electrical power engineering. Since 2006 he is honorary professor at Budapest Polytechnics. Since 1979 he is working with 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, Budapest, Riga, Tallinn, Varna, Prague and Ostrava.
E-mail: michal.kolcun@tuke.sk

György Morva graduated from Electro-Mechanics Faculty of Leningrade Polytechnical Institute in 1975. In 1988 received scientific degree of technical sciences (Dr. sc. ing.) at the Hungarian Academy of Science. He has been working in Kando College from 1976 as a senior lecturer, assistant, Associate Professor and Professor of Power Engineering Institute. His research interests include Electrical Power System Control & Relay protection. Address: Balassi B. 9–11, 1055. Budapest;
Phone: +36309417641;
E-mail: morva@uni-obuda.hu

Zsolt Čonka is a PhD student in the Department of Electric Power Engineering at the Faculty of Electrical Engineering and Informatics at Technical University in Košice. He received a master degree in electric power engineering on subject improving transient stability. His scientific research is mainly focused on research of special devices for power flow and transient stability.
Address: Mäsiarska 74, 04120, Košice, Slovakia;
Phone: +4210556023562;
E-mail: zsolt.conka@tuke.sk