VQ IMPACT OF THE RENEWABLE DISTRIBUTED ENERGY SOURCES

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ABSTRACT

This paper deals with the impact of renewable energy sources (RES) on the voltage quality (VQ) parameters in low voltage (LV) distribution grids. This impact is demonstrated by study of VQ measurements in 23 other LV distribution grids. This paper follows in already published paper [2].

INTRODUCTION

The supply territory of E.ON Distribution in the Czech Republic, run by E.ON Czech Republic, accounts for approximately 1.5 million customers. More than 900MW of photovoltaic (PV) plants were connected to this network. The mass operation of generating plants also results in poorer voltage quality parameters in the distribution network. The operation of each power plant, including a small one, increases the voltage values in the place of connection to the distribution grid. In case of accumulation of sources in one part of distribution system, it is possible that overvoltage will occur respective voltage variations will not comply with the requirements of the standard EN 50160. Theoretical impact of RES on voltage quality was described in many papers, but practical experience of RES operating in real distribution grids are not available, or are available only in case studies. So 23 other representative LV distribution grids with PV plants were chosen and these grids were measured.

GRIDS WITH PV PLANTS

Description of grids with PV plants

In each LV grid were made two week VQ measurements at the same time, first in the substation (LV level respective output of the transformer 22kV/0.4kV – point U2 in the Fig. 1) and second in the point of connection of PV plant to LV distribution grid (supply terminal of PV plant - point U4 in the Fig. 1). In each point of measurement was calculated parameter short circuit power (Sk”). The nominal active power (AP) of each PV plant was available.

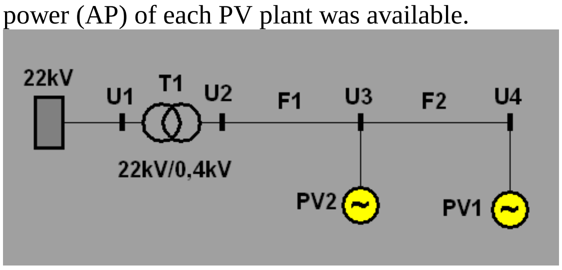

Fig. 1: general block diagram of measured LV grids

Measured PV plants in Fig. 1 are connected in the point U4. Other operated PV plants in the some LV feeder (when exist) are connected in the point U3. When other PV plants do not exist active power of PV2 is zero (see Tab. 1). T1 is distribution MV/LV transformer, F1 and F2 are LV feeders. In points U2, U3 and U4 are connected customers with load. From feeders F1 and F2 are supplied other customers (only with load), but these are not marked in the Fig. 1 (for a simplicity).

grid	power of T1	Sk" [MVA]		AP of PV [kW]	
No.	[kVA]	U2	U4	PV1	PV2
1	250	6,28	0,6	4,8	5
2	400	9,55	1,01	21	14
3	400	9,52	2,55	3	18
4	400	9,52	0,43	5	0
5	400	9,51	0,9	24	14
6	160	4,14	1,78	79	0
7	400	9,52	3,76	4	0
8	400	9,52	0,4	19	3
9	630	13,9	1,39	7	3,5
10	400	9,55	2,63	13	0
11	160	4,14	0,67	28	0
12	100	3,23	1,07	9	30
13	250	6,26	0,406	7	10
14	250	6,04	0,28	15	0
15	160	4,15	0,44	5	0
16	160	4,14	0,89	19	0
17	250	6,25	0,25	5	0
18	630	16,36	0,87	9	0
19	400	9,52	0,84	7	0
20	250	6,16	1,46	4	0
21	400	8,41	0,46	12	0
22	630	16,28	1,18	6	0
23	400	9,5	1,57	30	30

Tab. 1: parameters of measured LV grids

VQ measurements and the EN 50160 standard

All the measurements were evaluated according to the EN 50160 standard [1]. Under normal operating conditions excluding the periods with interruptions, supply voltage variations should not exceed ± 10% of the nominal voltage Un. Test method for low voltage level (under normal operating conditions) is following [1]:

- During each period of one week 95% of the 10 min mean r.m.s. values of the supply voltage shall be within the range of Un ± 10%; and
- All 10 min r.m.s. values of the supply voltage shall be within the range of Un + 10%/-15%

Also when one 10 min mean r.m.s. value of the supply voltage exceeds during the week the limit Un + 10% (110% Un), it results in overvoltage and voltage quality respective voltage variations will not comply with the requirements of the standard EN 50160.

Evaluation of VQ measurements

Campaign 2011

The measurements were under way from May to July 2011.

Grid	V100%max [%Un]		V100%min [%Un]	
No.	U2	U4	U2	U4
1	105,78	108,17	102,33	95,53
2	106,63	107,59	103,35	101,37
3	109,31	109,46	103,77	99,73
4	104,59	107,23	101,56	95,11
5	105,76	107,39	102,44	100,31
6	109,14	110,89	103,77	101,44
7	105,41	106,23	101,26	99,88
8	106,47	107,96	102,57	98,28
9	106,27	106,35	103,05	100,62
10	106,58	106,79	103,32	102,96
11	106,04	107,34	100,63	98,20
12	106,00	107,07	101,33	98,65
13	105,74	106,38	101,63	100,89
14	106,07	110,97	102,74	95,13
15	107,15	108,64	103,20	94,86
16	106,80	108,87	102,59	101,32
17	109,30	112,22	106,13	103,06
18	105,26	107,87	101,36	96,33
19	104,91	106,11	99,54	97,67
20	105,84	106,13	99,48	97,24
21	106,30	110,03	102,48	99,84
22	110,47	110,54	105,90	103,89
23	107,80	112,55	98,70	96,86

Tab. 2: evaluation of maximal/minimal 10 min mean r.m.s. values of supply voltage (V100%max/V100%min) in 23 LV grids during week measurements in points U2 (substation) and U4 (PV plant No. PV1) – campaign 2011

From Tab. 2 you can see, that in 6 cases (grids No. 6, 14, 17, 21, 22, 23) was overvoltage evaluated (V100%max>110% Un). In case of the grid No. 22 was overvoltage evaluated in the substation too, but the overvoltage was caused by bad set tap charger on the distribution transformer. In cases of grids No. 6, 14, 17, 21, 23 was overvoltage evaluated only in the supply terminal of PV plant, voltage variations in the substations comply with requirements of the standard EN 50160. The overvoltage in these cases (grids No. 6, 14, 17, 21, 23) is caused by operation of PV plants. Also in 22% (5/23*100%) of LV grids with PV plants voltage variations do not comply with the requirements of the standard EN 50160 and solutions of this problem have to be found.

Campaign 2012

We wanted to eliminate overvoltage in grids No. 6, 14, 17, 21, 22, 23 (see Tab. 2) also we set the tap changer on off-regulated distribution transformers in these cases. By tap changer setting should occur voltage decrease on the outputs of MV/LV distribution transformers in cases of grids No. 6, 14, 17, 21, 22, 23. This campaign 2012 was realised in the same 23 LV grids as in year 2011 and the VQ measurements were under way from April to August 2012.

Grid	V100%max [%Un]		V100%min [%Un]	
No.	U2	U4	U2	U4
1	106,15	107,62	102,61	90,98
2	106,37	107,52	103,31	102,25
3	107,86	107,00	103,62	100,12
4	104,51	105,49	101,09	91,60
5	106,87	107,74	100,74	98,17
6	106,50	107,70	100,89	98,25
7	104,44	104,76	100,21	98,63
8	106,21	106,61	99,98	95,25
9	106,58	107,52	104,24	100,47
10	106,87	106,91	104,30	102,76
11	105,96	107,43	102,00	97,72
12	104,87	105,88	102,04	98,29
13	105,00	108,13	102,56	94,68
14	103,44	106,87	99,66	94,40
15	106,96	109,18	103,74	92,33
16	104,98	106,65	100,68	97,78
17	103,96	112,41	100,69	99,92
18	105,32	106,91	100,89	93,69
19	103,97	105,25	99,50	96,77
20	105,68	106,76	99,17	96,91
21	103,69	106,51	100,29	93,03
22	107,46	107,63	101,60	97,35
23	101,50	106,27	98,43	98,24

Tab. 3: evaluation of maximal/minimal 10 min mean r.m.s. values of supply voltage (V100%max/V100%min) in 23 LV grids during week measurements in points U2 (substation) and U4 (PV plant No. PV1) – campaign 2012

Comparison between campaign 2011 and campaign 2012

From Tab. 3 you can see that overvoltage in grids No. 6, 14, 21, 22, 23 was eliminated but overvoltage in grid No. 17 stays. Also we can say that by setting the tap changer on the MV/LV transformer was eliminated overvoltage in 5 of 6 cases. After this remedy already (22/23)*100=96% grids conform EN 50160 standard from view of voltage variations.

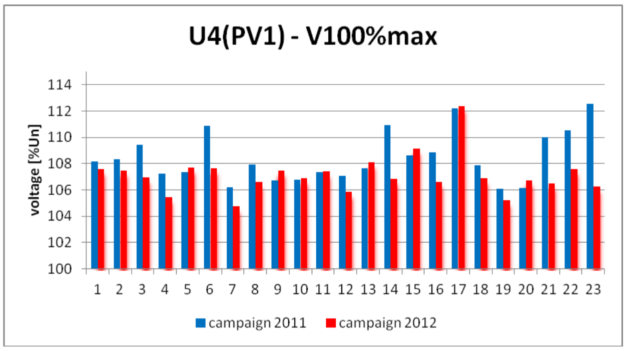

Fig. 2: evaluation of maximal 10 min mean r.m.s. values of supply voltage (V100%max) in 23 LV grids during week measurements in the point U4 (PV plant No. PV1)

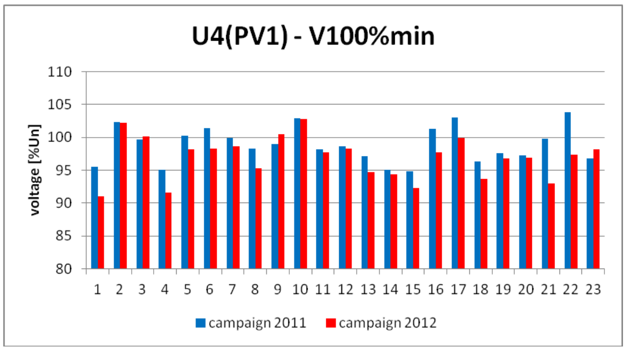

Fig. 3: evaluation of minimal 10 min mean r.m.s. values of supply voltage (V100%min) in 23 LV grids during week measurements in the point U4 (PV plant No. PV1)

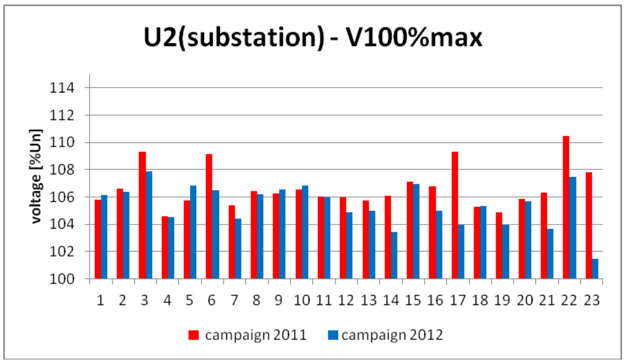

Fig. 4: evaluation of maximal 10 min mean r.m.s. values of supply voltage (V100%max) in 23 LV grids during week measurements in the point U2 (substation)

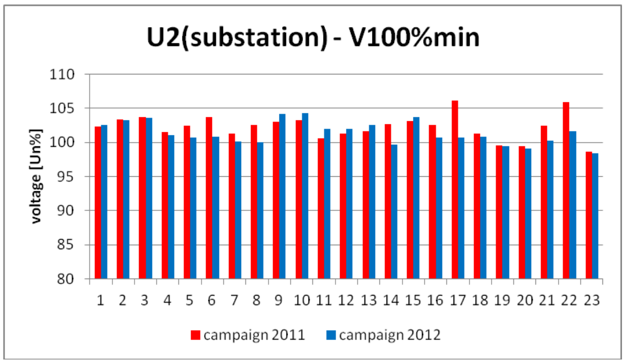

Fig. 5: evaluation of minimal 10 min mean r.m.s. values of supply voltage (V100%min) in 23 LV grids during week measurements in the point U2 (substation)

Limit value for flicker (Plt=1) was exceeded in 10 grids (43%) for each campaign.

GRIDS WITHOUT PV PLANTS

In each LV grid were made two week VQ measurements at the same time, first in the substation (LV level respective output of the transformer 22kV/0.4kV) and second at the end of the longest LV feeder. In the LV grid was connected no PV plant. Measurements in 21 other representative LV distribution grids were made previously in years 2009 and 2010 for flicker detection in LV grids. You can assume overvoltage in the substation due to bad set tap changer or low voltage at the end of the feeder due to its length or big load.

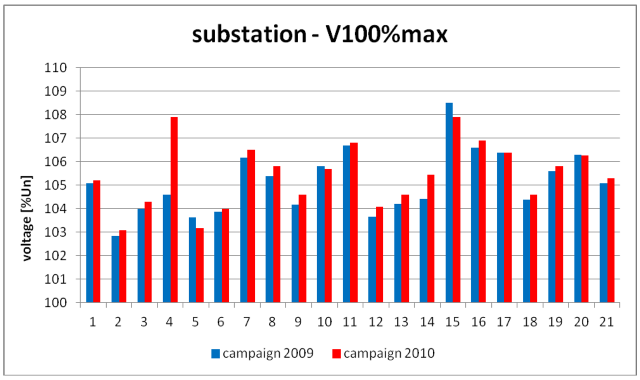

Fig. 6: evaluation of maximal 10 min mean r.m.s. values of supply voltage (V100%max) in 21 LV grids during week measurements in the substation

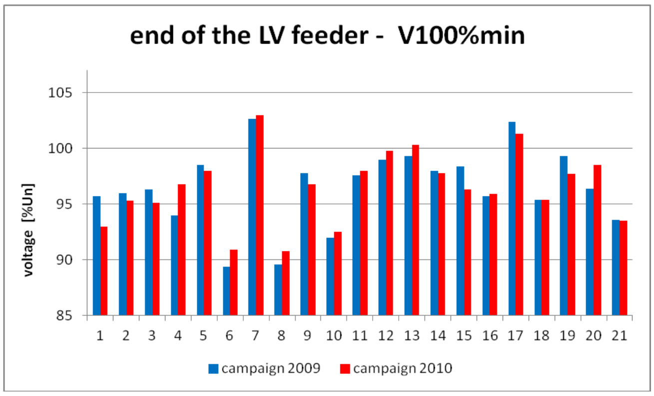

Fig. 7: evaluation of minimal 10 min mean r.m.s. values of supply voltage (V100%min) in 21 LV grids during week measurements at the end of the LV feeder

In all the grids without PV plants were detected voltage variations meeting the requirements of the EN 50160 standard. Limit value for flicker (Plt=1) was exceeded in 8 grids (38%) for each campaign.

VQ COMPARISON BETWEEN LV GRIDS WITH AND WITHOUT PV PLANTS

Type of grid/VQ parameter	Voltage variations	Flicker Plt
Without PV plant	0%	38%
With PV plant	22%	43%
With PV plant*	4%	43%

Tab. 4: percentage number of grids which do not meet voltage variations or flicker according to the EN 50160 standard

From Tab. 4 you can see that 38% of grids without PV plants are inconvenient from view of flicker and all the grids meet voltage variations. 43% of grids with PV plants are inconvenient from view of flicker and 22% of grids with PV plants do not meet voltage variations due to the operation of these PV plants. 4% of grids with PV plants* do not meet voltage variations not after remedy – tap changer setting.

CONCLUSION

It was demonstrated that operation of RES in the LV distribution grids causes poor voltage quality and problem with overvoltage has to be solved in approximately 22% LV grids. It is also a question how voltage quality will develop in the LV distribution network due to the operation of a growing number of distributed energy resources. The experience of electricity distributor shows that the number of LV grids with nonconforming VQ will grow due to operation of the disperse resources.

REFERENCES

[1] EN 50160 Ed.3 Voltage characteristics of electricity supplied by public distribution systems. Brussels: European Committee for Electrotechnical Standardization, 2010. 20 p.

[2] M. Kaspirek, D. Mezera, 2012, Study of VQ measurements in LV distribution grids with PV plants, *Proceedings CIRED 2012 – Workshop*, paper 0038, ISSN 2032-9628