PROBLEMS OF VOLTAGE STABILIZATION IN MV AND LV DISTRIBUTION GRIDS DUE TO THE OPERATION OF RENEWABLE ENERGY SOURCES

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ABSTRACT

The supply territory of the company E.ON Distribution in the Czech Republic (run by the company E.ON Czech Republic) accounts for approximately 1.5 million customers. More than 900MW of photovoltaic (PV) plants were connected to this distribution grid. It was detected the problem with overvoltage in approximately 20% low voltage distribution grids with connected PV plants and this problem has to be solved. The problem with high voltage variance is caused partially due to the operation of PV plants connected into the MV distribution grid and partially due to the operation of PV plants connected into the LV distribution grid. It is supposable, that the problem with overvoltage will occur when PV plants are connected both into the MV and into the LV distribution grid in the same part of the grid. In order to cope with the increased level of distributed generation new solutions for grid operation and new technologies are needed. In the paper are described three solutions for voltage stabilization. These proposed solutions prevent nonconforming voltage quality (overvoltage) according to the EN 50160 standard and following investments.

INTRODUCTION

Figure 1 shows the growing number of connected dispersed power sources. The number of connected power sources and installed capacity of these power sources are approximately ten times higher today as in year 2008. The cause of this number connected renewable energy sources (RES) is a bountiful policy of the state. The most of connected RES are PV plants but connecting of biogas plants is very popular in the last time. The experience of distribution network operator (DNO) shows the problem with the operation of these renewable energy sources (RES). 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 50 160 [1]. All 10 min r.m.s. values of the supply voltage shall be within the range of nominal voltage 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.

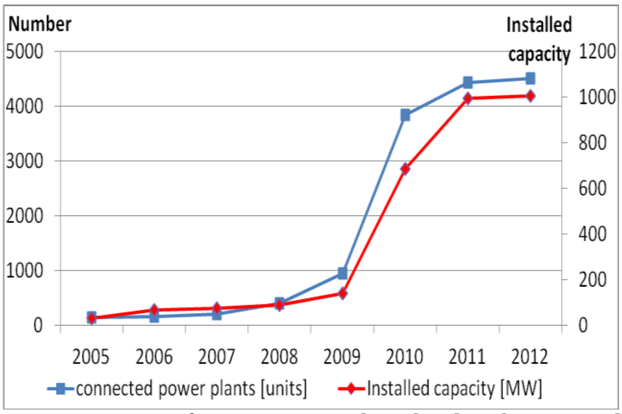

Fig. 1: History of RES connected to the distribution grid E.ON in the Czech Republic

OPERATION OF THE DISTRIBUTION GRIDS

Grids without connected RES

It is operated voltage level 23.1kV (105%Un) on the output of the HV/MV transformer with the tolerance +/-0.3kV (see Fig. 2). When no loaded medium voltage (MV) grid and no connected RES to this grid voltage can reach the value of 106. 36%Un in the MV distribution grid. When no loaded LV grid, no connected RES to this grid and no loaded MV grid at the same time voltage can reach the value of 106.36%Un in the LV distribution grid. This creates a reserve with the relation to the upper limit of voltage variations according to the EN 50 160 standard. When representative loaded MV grid and no connected RES in this grid voltage can reach the value of 99. 6%Un in the MV distribution grid. When no loaded LV grid, no connected RES to this grid and representative loaded MV grid at the same time voltage can exceed the lower limit 90%Un in the overhead LV distribution grid – see Fig. 2. Under normal operating conditions excluding the periods with interruptions, supply voltage variations should not exceed ± 10% of the nominal voltage Un when there is usual the voltage decrease 10%Un caused by load in the overhead LV distribution grid. This problem with low voltage in overhead LV distribution grids is continuously, long-term and systematic solved.

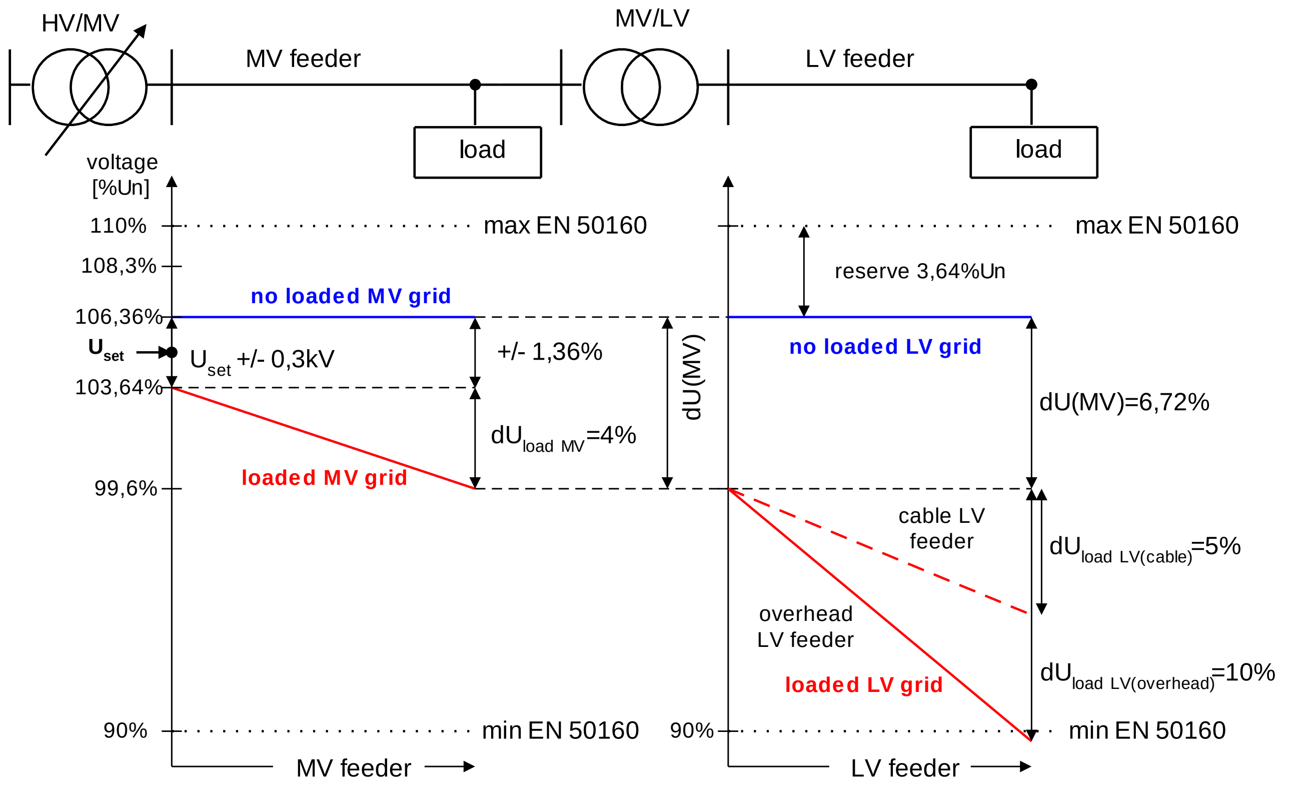

Fig. 2: voltage in MV and LV grids without connected RES

Grids with connected RES

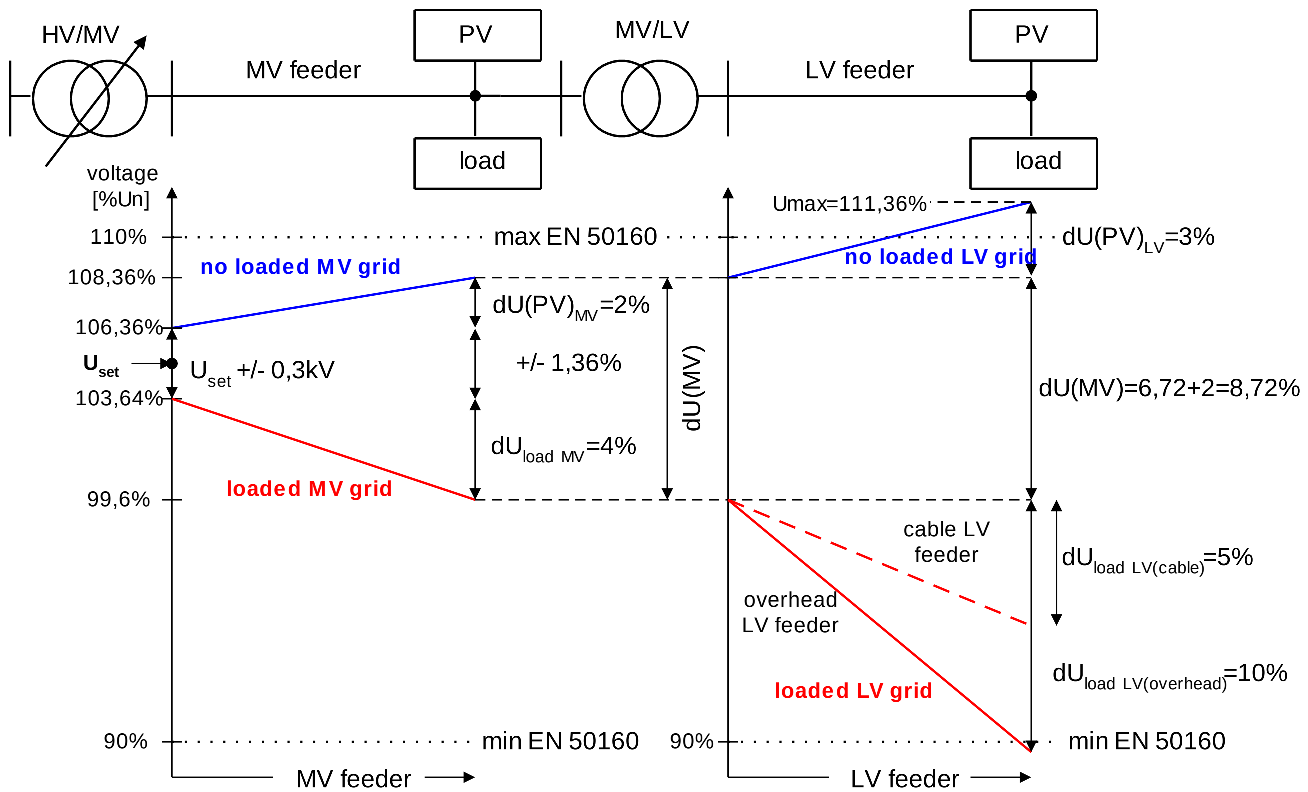

Fig.3: voltage in grids with connected RES

The most of RES are connected to the MV and LV distribution network. According to the present standards the operation of power sources can cause voltage increase 2%Un in MV distribution grid and 3%Un in LV distribution grid. Consideration of the connection to the LV grid is realized independent of power sources operating in MV grid. In case of connected power sources in MV grid and LV grid in the same part of distribution system voltage increase caused by operation of power sources can reach the value 5%Un in relation to LV grid. So when no loaded MV and LV grid overvoltage will occur by operation of RES – see Fig. 3. The problem with overvoltage caused by operation of RES is not only theoretical but was demonstrated by voltage quality (VQ) measurements in 23 other distribution grids [2]. The current way of grid operation and voltage control is insufficient when RES operate in distribution network. The voltage level in MV and LV grid should not be set fixed already. Voltage in MV and LV grid has to be controlled variable.

REMEDY TO STABILIZE THE VOLTAGE

RES (particularly PV plants) produce the power unpredicted and variable so it is necessary to control the voltage quick.

Variable controlled HV/MV transformer

Changes of the set voltage level on the output of the on-load regulated substation transformer 110/22kV were tested, when this voltage value is set today fixed during the year. Impact of these changes on voltage stabilization was tested in real operated MV distribution grid with many connected PV and wind power plants.

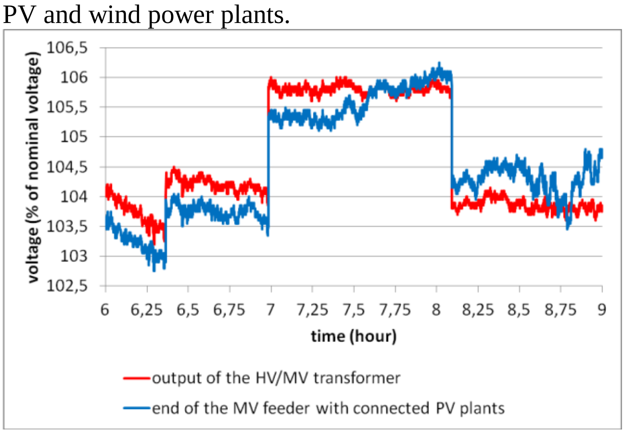

Fig. 4: measured voltage by the test of voltage increase on the output of the HV/MV transformer

The test of voltage increase was realized at the time of loaded MV and LV grid with the goal to eliminate undervoltage in the LV distribution grid. From Fig. 4 you can see no problem with voltage variations in MV grid when voltage was increased on the output of the HV/MV substation transformer.

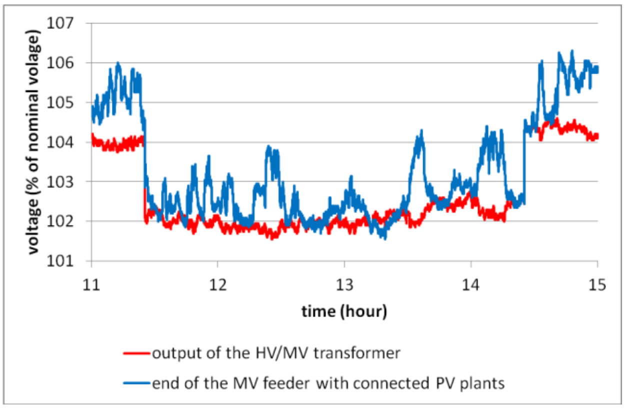

Fig. 5: measured voltage by the test of voltage decrease on the output of the HV/MV transformer

The test of voltage decrease was realized at the time of operated PV plants in MV and LV grid with the goal to eliminate overvoltage in the LV distribution grid. From Fig. 5 you can see no problem with voltage variations in MV grid when voltage was decreased on the output of the HV/MV substation transformer.

The results of tests show it is possible to set variable the value on the output of the HV/MV transformer and voltage in distribution grid will be stabilized in the allowed range.

Reactive power regulation impact of power sources

Reactive power regulation impact of power sources connected into the MV distribution grid is described theoretically when real MV grid with many power sources was chosen and voltage calculation by power factor changes was made. When $dU_{ref=}$100% is defined as a voltage change between the MV substation (output of the HV/MV transformer) and power source operating in the MV grid (at the end of the MV feeder) under nominal conditions of this power source (the source provides nominal active power by set PF=1) you can reduce this value theoretically up to zero by means of reactive power load. For reactive power load (by preservation of nominal power supply of regulated power source) the power factor of power sources has to be changed. If power source takes reactive power from the grid this source is underexcited.

$PF_{underexcited}$	1	0,95	0,9	0,85	0,8
dU_{ref} [%]	100	58	38	20	1

Tab. 1: elimination of voltage increase by setting the PF of all the sources connected to the part of MV grid supplied from substation HV/MV distribution transformer

Present power source allow setting the power factor from value 1 to 0.95. From Tab. 1 you can see the voltage increase reduction allows only 58% of dU_{ref} by the set PF=0.95. For total reduction (in Tab. 1 reduction to 1%) is set PF=0.8 needed.

Self regulated MV/LV substation transformers

The solution of voltage stabilization in LV distribution grid can be the operation of distribution transformer MV/LV (22/0.4kV) with on-load tap changer (self regulating transformer). Such a transformer with on-load tap changer is several times more expensive than transformer with off-load tap changer but operation costs are saved. When transformer with off-load tap changer is used supply interruption is necessary for setting the tap changer. Setting the off-load tap changer is made manually when arrival and work of electrician is needed.

Fig. 6: transformer with off-load tap changer, detail of tap changer

Two LV grids with PV plants were chosen and voltage variations were measured in the substation (LV level) and in the point of connected PV plant. We plan to install self regulated distribution transformers to these grids during the year 2013. Then we will consider the impact of the operation of the on-load regulated distribution transformer on voltage variations in the LV grid. In year 2012 we had to choose the concrete producer so we made a market inquiry. Some producers were able to deliver self regulating MV/LV transformers.

producer	Regulation range [%Un]	Weight [kg]
Magtech	-6%	2600
Efacec	+/- 4x2,5%	3950
Reinhausen	+/- 4x2,5%	2760
Siemens	+/- 3,44	1650

Tab. 2: some producers and technical parameters of self regulating MV/LV distribution transformer

Comparison in Tab. 2 was made for distribution transformers of nominal power 400kVA. For testing in two distribution grids we chose the type Siemens. This type has no standard tap changer but the voltage control takes advantage of power electronics.

Fig. 7: substation (and MV/LV transformer with off-load tap changer) for using the self regulating transformer

CONCLUSION

It was demonstrated that the use of new technologies and new systems of voltage control is needed. Some tools to stabilize voltage in distribution grid were described in this paper. When smart grids are designed they have to solve the problem with voltage control in the distribution grid too.

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