NETWORK HOUSEKEEPING WITH STRETCHED LOW VOLTAGE LIMITS

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ABSTRACT

This paper looks into solutions a grid operator has to cope with, taking into account high penetration of high penetration of renewable sources and new loads in the LV grid. Next to that it answers the following main research questions:

- what will happen when the low voltage limits will be stretched from ±10% (current value) to e.g. ±15% (with or without time limitation)?

- what must a DSO do to realise such a change (technical, legal, ….)?

To answer these questions a literature study, simulation, tests and extensive surveys amongst key stakeholders were performed.

Finally, recommendations and alternatives are proposed towards the community of DSOs following EN50160.

INTRODUCTION

The growing penetration of distributed generators connected to the low voltage grid will result in increased voltage variations. Because the minimal quality of the voltage at the point of coupling with a customer is prescribed in the national Grid Code and EN50160, grid operators need to take appropriate measures to ensure the quality remains within the allowed limits.

Mainly in Germany PV inverters sometimes are switched off when the local voltage becomes too high to prevent damage of the inverter and other grid connected appliances. Also in The Netherlands and Belgium such cases are known, although very limited. Because the number of such cases is growing, grid operators have to investigate which countermeasures are most efficient. Currently they have to solve problems with grid congestion or power quality by expensive grid reinforcements.

OBJECTIVE

First, an overview will be given of the possibilities a grid operator has to cope with high penetration of renewable sources and new loads in the LV grid. Next to that it answers the following main research questions:

- What will happen when the low voltage limits will be stretched from ±10% (current value) to e.g. ±15% (with or without time limitation)?

What must a DSO do to realise such a change (technical, legal, ….)?

OPTIONS ANALYSIS

If the penetration level of generators gets as high in Belgium & The Netherlands as in Germany, there is a chance more problems will occur, like:

- Increased voltage variations will result in more and frequent shut down of PV inverters, with loss of production as a result;
- Decreased stability of the electricity grid if PV inverters are not supporting the grid in case of large disturbances;
- Increased harmonic distortion of the grid voltage.

Technical solutions

The grid operator, responsible for the distribution of electrical energy, has multiple technical options to solve problems with congestion or power quality. Solutions used nowadays are increasing the capacity of the grid with new cables and transformers (grid reinforcement) or controlling the low voltage automatically with e.g. line voltage controllers. Automating the tap changer can help a lot to stabilize the voltage and can increase the hosting capacity with a factor of at least two if the load and generation are evenly divided. Such grid reinforcements are expensive and it will cost a lot of time to upgrade many parts of the grid. Although this is a very robust way of solving problems with the grid, it's not clear if this is the solution with the least cost for society and if such an adaptation can be realised in time.

Other solutions, with which experiments are ongoing (in Germany), are:

- Reactive power control by inverters;
- Demand/supply side management and storage.

Nowadays the two solutions above are not possible in The Netherlands and Belgium from a legal point of view.

In Germany PV inverters (above 3,68 kVA) have to support the grid, which can increase the hosting capacity with a factor two for PV and is on average probably cheaper than reinforcing the grid everywhere.

Another scenario is to decouple the grid voltage from the in-house voltage with an converter on the connection point. Although this is a possible technical solution it's practically impossible to implement this in all homes. Such an inverter would be big and expensive and it should be very reliable and not cause other grid disturbances

Grid code and/or Standard adaptation

Another way of looking at the problem is to allow the increased voltage variations and to adapt the Grid Code and EN50160 with new limits for slow voltage variations. Two possible new limits were tested:

- Increasing the maximum allowed voltage of Un+10% to Un+15%, probably with a time limitation;
- Decreasing the minimum allowed voltage of Un-15% with a time limitation of 5% to Un -15% permanently or with a more optimal time limitation.

Simulations, survey and tests

Power flow simulations in actual Dutch and Belgium grids showed that these new limits increase the hosting capacity for PV in LV grids. Mainly existing grids would benefit from such increase of the allowed voltage variations, new grids are stronger and can deliver a more constant voltage quality.

In practice there are many drawbacks for such adaption of the LV voltage limits, safety and performance will be affected.

A survey was performed to gather a wide spectrum of expert views. Therefore key persons representing different stakeholders have been interviewed: manufacturers of household appliances, manufacturers of inverters, regulators, network operators and independent PQ experts.

General opinions were:

- Increasing the maximum allowed voltage to Un+15% is no realistic solution because of the impact on the equipment;
- Decreasing the allowed voltage to Un-15% would be less problematic considering safety, impact on performance would still be an big issue;
- A change of the voltage limits would again require a long transition period, comparable with the change from 220V to 230V;
- Storage and demand side management is believed to be more promising on the short term.

Also tests showed that performance of appliances with electric heating [Figure 1] and lighting is affected and motors are vulnerable to. Lifetime degradation becomes an issue mainly for higher voltages.

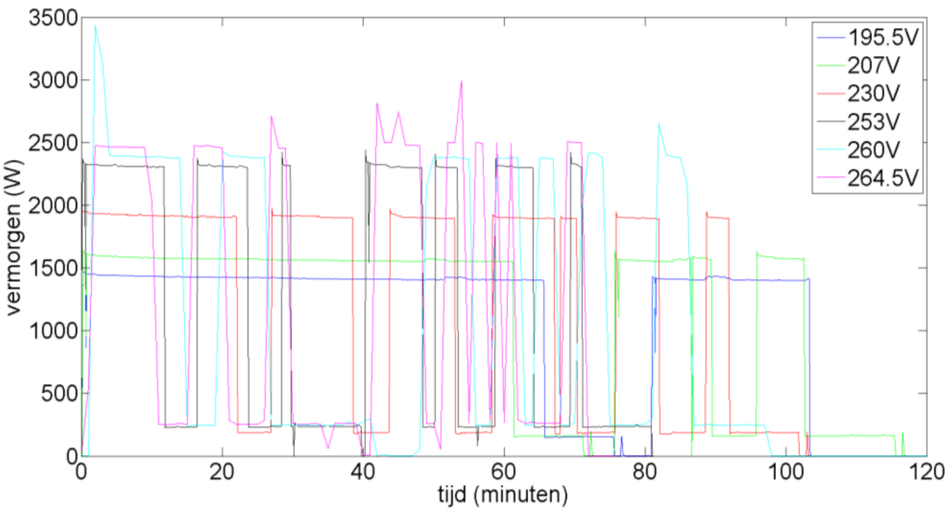

Figure 1 Example: Power consumption of the dryer with energy label B [4]

Safety is not directly an issue for the tested new voltage limits. Shut down of appliances with electric heating (to protect the from overheating), like an oven, washing machine, dryer is possible at voltages above Un+7%. Also some small household transformers and universal motors used in many household appliances will heat up. Industrial appliances connected on LV are affected to, but are not treated in this paper.

If all opinions, costs, benefits, pros and cons are taken into account, the most promising scenario is to allow the voltage to be Un-15%, possibly with a new time limitation (e.g. for 10% in a week, or 5% in a longer period than a week). Currently Un-15% is only allowed for 5% of the time in a week.

Such scenario will result in:

- Hosting capacity for PV is increased when the LV busbar voltage is lowered from ±240V to ±230V,
- Tests showed most household appliances can operate without problems on Un-15% although often they have to perform their task longer, power controlled devices are very tolerant to

voltage variations;
- Performance of heating devices, lighting and motors must be reviewed to prevent too much comfort or performance losses;
- Lifetime of most components will be extended when a lower voltage is applied.
- No direct problems with safety are expected after this research, on the long term this should be investigated.

Possible implementation

A transition period short enough to deal with the possible upcoming problems is achievable if all stakeholders consider it as a suitable solution.

Extensive lobbying is required to convince all stakeholders to investigate new voltage limits on low voltage. Such lobbying is required because a change of the low voltage limits affects all relevant standards and consequently the safety and performance of all connected equipment on low voltage.

INCREASING NEED FOR POWER

Next to the increase in distributed generators in the grid, households will on average need more power in the future despite of energy efficiency measures. Heat pumps, EV's, wellness and PV increase the need for more available connection capacity to the public grid (that is, if no in-home energy management system mitigates this peak capacity need).

It's desirable to connect 'heavy' appliances by three phases, such as a heat pump, a home charger for EV or 'large' PV installations. Although this requires a higher investment in the connection and installation, using three phase equipment has a positive effect on the LV unbalance.

Offering all homes standard a three phase connection of 3x25A is, in cases where no three phase equipment will be present, not desirable although it can increase customer satisfaction and make homes more future proof for EV charging. Currently there are not many homes with a three phase connection in The Netherlands. The major drawbacks of the standardization of the three phase connection are:

- Possible increase of the LV unbalance (installers are responsible for balancing load in the homes and even on the grid, instead of the grid operator);
- Customers who don't need three phases pay too much for their own 3-phase installation, which could be single phase installation in many cases;
- It is more difficult to integrate storage in the home, one phase with PV and storage is easier to balance and cheap to realize.

In Belgium there is the reverse trend of connecting new homes with a single phase.

RECOMMENDATIONS

1. To start lobbying to investigate the possibilities to change the time limitation of the lower voltage limit on low voltage;

2. To adapt PV inverters in the Netherlands which still have a disconnection setting of Un+6% to the new standard limits imposed by the local grid operator (often Un+10%);

3. To permanently lower the voltage of the LV busbar in areas with many PV panels to prevent PV inverters to switch off during peak moments in production;

4. To investigate further the indirect control of the voltage by integrating storage and demand side management behind the connections;

5. To convince installers of the importance to use the three available phases correctly. They are now the main responsible for load balancing in new homes in the zone of Alliander.

ACKNOWLEDGMENTS

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