Control concept for active low voltage distribution networks

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Abstract – The following proposal describes the results of the first phase within the research project "DG DemoNet – Smart LV Grid". The consortium out of distribution system operators (DSOs), research institutions and industry partners have defined a set of control strategies for active low voltage grids. Each strategy can be seen as successive stages, which on the one hand are increasing in complexity of the components involved and the need to communicate with them, on the other hand allow a more and more optimal operation of the distribution grid.

6. Introduction

Low voltage distribution networks need to host an increasing amount of distributed generation (DG) as well as new network participators such as electric vehicles. First approaches for active voltage control to increase the hosting capacity are currently introduced in medium voltage networks [1].

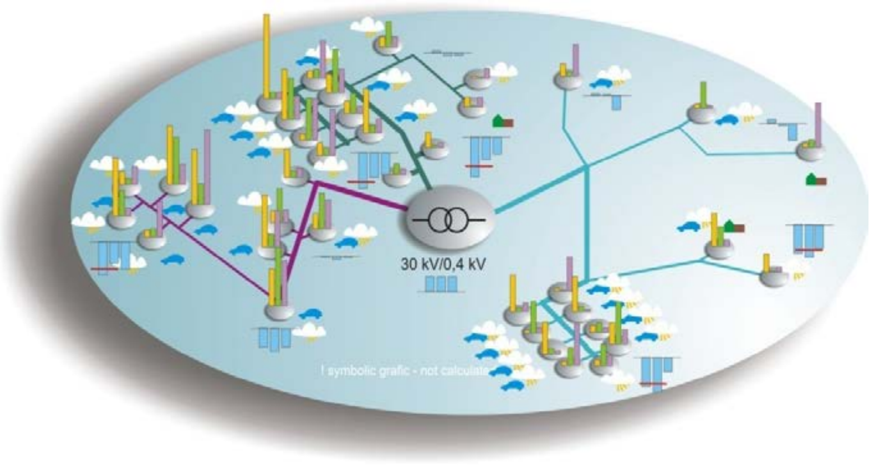

Figure 1: Photovoltaic and e-mobility are major drivers for introducing smart grid approaches in low voltage distribution networks (source: A. Abart, Energie AG)

Based on detailed modelling and analysis of LV networks [2], [3] different approaches will be demonstrated:

1. Intelligent planning: The work within this task considers new planning methods, like probabilistic planning, enabling higher DER densities.
2. Intelligent monitoring resulting in new monitoring solutions, which improve the certainty in grid planning and further support the grid operation.
3. Active management and control using AMIS Smart Grid Metering infrastructure as existing communication network. Use of the AMIS system will result in new and cost-effective active low voltage network control solution approaches enabling higher DER densities

In the project "DG DemoNet – Smart LV Grid", real tests of solution approaches for central and distributed monitoring, management and control concepts will be performed in selected low voltage (LV) networks in Salzburg and Upper Austria [4]. The project aims to create actual voltage problems in these selected network segments by integrating a high share of photovoltaic (PV) and e-mobility. By implementing the developed control concepts the problems will be solved.

7. Overall smart control concept

The following figure shows the 5 stages of the control concept which should be implemented in a low voltage grid controller (LVGC) build-up of standard automation components and a robust industrial PC.

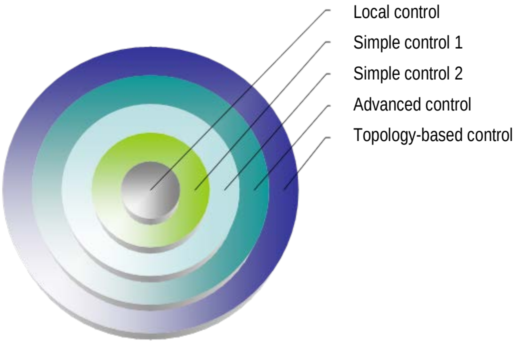

Figure 2: 5 stages of control concept

This structure takes into account the increasing complexity during development process.
After verification of the functionality by co-simulation, based on models of low voltage grids and communication channel behaviour, the stages of the concept can be implemented in a controller test environment. The development process is finished after a hardware-in-the-loop (HIL) run under real test conditions.

With this procedure the concept can be demonstrated step by step in real low voltage grids. The findings after realization of each stage will be used to enhance the next stages.

7.1 Stage 1: “local control“

Local “actors”, like PV-inverters [5], transformers with on-load-tap-changer and e-vehicle charging stations have to ensure their local voltage limits according EN50160. Additionally this stage is the fall back strategy in case of loss of communication in one of the next stages.

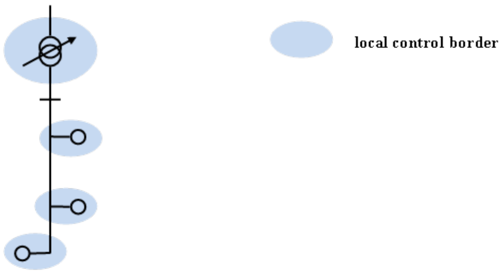

Figure 3: concept of stage 1 – “local control”

There is no communication between the grid controller and the mentioned “actors” of the system. Each local actor works on his own, taking into account local available measurement values of the voltage and try to stabilize it with the help of a locally acting controller.

7.2 Stage 2: “simple control 1“

The enhancement in stage 2 is the integration of voltage measurements in the network in a simple optimization algorithm for transformer tapping. The communication infrastructure is used to get information of the actual voltage band violations to control the voltage level in the system. The other actors like PV-inverters and e-mobility charging units are still in droop control mode as well as in stage 1.

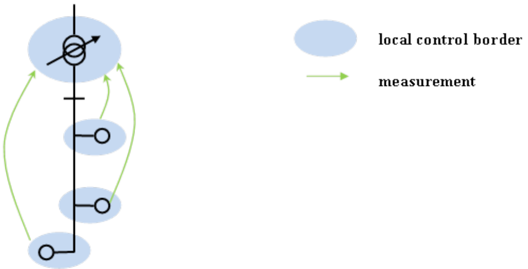

Figure 4: concept of stage 2 – “simple control 1”

There is only a unidirectional communication from the components of the grid (especially smart meters) to the grid controller LVGC.
One limitation in this stage is that, due to the limited bandwidth of the communication, not all smart meters can be used as measuring points. Therefore, a previous selection of for the control relevant measuring points has to be performed. This selection can be done by off-line analyses of the low voltage grid and "program" the LVGC with the determined points.
Another, more sophisticated way would be that this selection is performed on-line by the LVGC with no additional information, such as the topology of the grid, and therefore is able to dynamically adapt to changing conditions in the network. The algorithms for this automatic selection will also be applied within this project. The goal is a "plug and play" LVGC, which automatically derives from available measurement data an optimum selection of measurement points.

7.3 Stage 3: "simple control 2"

The next stage is to activate the communication to the actors within the grid. Additionally to the integration of voltage measurements in the network from stage 1, it is possible to give a system-wide strategy resulting in new set points for the locally acting controllers of the actors (e.g. dependence of the reactive power to the voltage for PV inverters) via broadcasts by the LVGC. This approach enables that all PV inverters are able to feed in a higher amount of active power as they could in stage 1. To ensure this, in this case a balanced penetration of inverters in the branches and on the phases has to be given.
The disadvantage of this sub-optimal solution is that also PV-inverters with weak influence to critical node voltages are starting feeding in reactive power for e.g. to increase the voltage or consuming reactive power to reduce it. This means that in total not the maximum possible amount of regenerative power from all PV-inverters is fed into the grid.

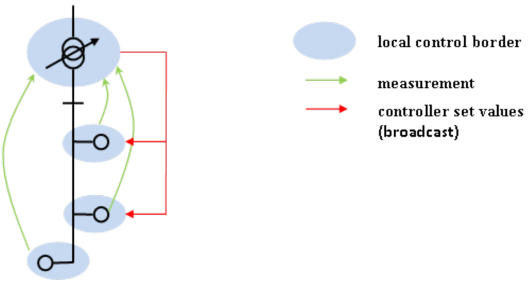

Figure 5: concept of stage 3 – "simple control 2"

There is a simple bidirectional communication now, but only a sub-optimal solution for the goal of maximising the feeding in of active power.

7.4 Stage 4: "advanced control"

To enable also heterogeneous distribution of PV and e-mobility, in this stage different coordinated optimization algorithms (i.e. maximize active power feed in with minimal reactive power flows) and coordinated dynamic controls using information and communication infrastructure will be introduced.

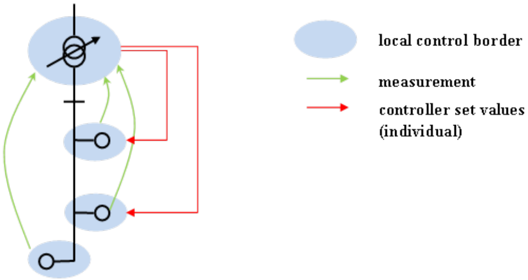

Figure 6: concept of stage 4 – "advanced control"

The "global" set points for the actors in stage 3 are substituted by individual set points for all active network components. The individual set points will be generated by the optimisation algorithm of the LVGC.

As in stage 2 much information about the low voltage grid and its actors is needed by the LVGC to address the actors properly. Also a selection of important measurement points is needed in this stage. A first approach is, to "engineer" this data by analysing the specific low voltage grids and program the operation parameters in the LVGC. When it comes to changes in the network (e.g. a new PV-inverter is installed), the parameters of the LVGC must also to be adapted every time to ensure an optimal operation.

Another approach is here, similar as in stage 2, to derive this information automatically from measurement data by the LVGC. The LVGC could rely on previous measurements or continuously collected measurement data and perform analysis, to derive the needed information. As a "plug and play" System, the LVGC will learn the network with time and react on changes.

7.5 Stage 5: "topology based control"

This stage is based on the previous stage "advanced control", but is also considering the information about the actual topology of the network in the optimization. This will allow to find the global optimum in case there are dynamic changes of the network topology (e.g. due to shifting of the sectioning point). Besides the measurement values from the smart meters is additional information required for the LVGC, to know about the changes in topology (e.g. switching states). This can also be derived by the additional installation of smart meter based "current guards" in all branches and selected nodes as additional measurement points.

Moreover also intelligent algorithm for topology estimation bases on Power Snap Shot Analysis (PSSA) [2], [3] will be applied and tested under real conditions. The biggest advantage here would be that no additional elements for topology recognition will be necessary.

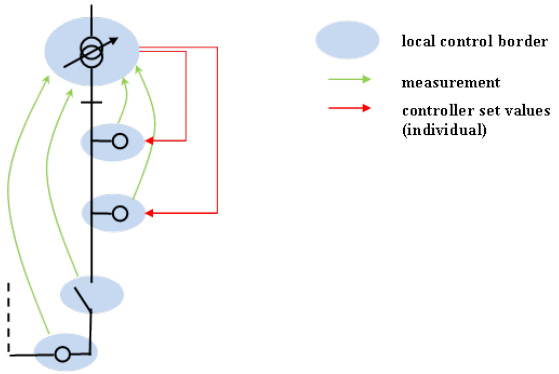

Figure 7: concept of stage 5 – "topology based control"

8. Summary and Outlook

The project "DG DemoNet – Smart LV Grid" aims to enable an efficient and cost effective use of existing grid infrastructures based on intelligent planning, on-line monitoring and active LV grid management concepts. In the selected low voltage networks a high share of photovoltaic and e-mobility will be implemented to bring future challenges into present and to test and validate future solutions to maximize the hosting capacity of the network infrastructure.
The development of the detailed control concepts within a co-simulation environment of power networks and communications networks, developed within the project "DG DemoNet Smart LV Grid" is ongoing. As already mentioned the related concepts will be designed, implemented and validated in real low voltage networks in Upper Austria and Salzburg, which are already selected within the first phase of the project. The field test will start in March 2013.

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Aknowledgement

The project “DG DemoNet – Smart LV Grid”, which tackles the increase of DG hosting capacity in the low voltage grid is founded by the Austrian Climate and Energy Fund and was started in March 2011.