CONTROL STRATEGIES FOR SMART LOW VOLTAGE GRIDS – THE PROJECT DG DEMONET – SMART LV GRID

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ABSTRACT

Upcoming challenges for LV grids include a high penetration of distributed energy resources and electric vehicles. The project "DG DemoNet – Smart LV Grid" aims to enable an efficient and cost effective use of existing grid infrastructures based on a three-step concept: intelligent planning, on-line monitoring and active LV grid management. Communication-based systems for automatic control concepts for low voltage grids are developed and demonstrated in pilot installations. This paper describes the results of the first phase within research project. The consortium out of distribution system operators, research institutions and industry partners have defined a set of control strategies for active low voltage grids.

INTRODUCTION

In the future, new requirements on the medium and low voltage distribution networks have to be fulfilled due to increased penetration of decentralized generation from renewable sources, but also due to new network participators like electric vehicles. This comes along with a paradigm shift. While distribution grid operation in the past got along without monitoring of real-time information due to adequate dimensioning, trends aim for more and more on-line monitoring. Consequently, active interventions during grid operation will be used in the future to guarantee voltage bands, line load conditions etc. This will be possible due to emerging technologies such as Smart Metering-related communication systems that improve the affordability of low voltage automation infrastructures.
Following this paradigm shift, the project "DG DemoNet – Smart LV Grid" searches for solutions for an active network operation at the low voltage level. The project, which tackles the increase of distributed generation (DG) hosting capacity in the low voltage and is founded by the Austrian Climate and Energy Fund, was started in March 2011.

First approaches for active voltage control to increase the hosting capacity are currently introduced in medium voltage networks [1]. Based on detailed modeling and analysis of LV networks [2], [3] different approaches will be demonstrated:

1. Intelligent planning (resulting in new planning methods enabling higher DG densities)
2. Intelligent monitoring (resulting in new monitoring solutions that improve the certainty of grid planning and support grid operation)
3. Active management and control using communication infrastructures restricted in bandwidth and availability (resulting in new and cost-effective active low voltage network control solution approach enabling higher densities of distributed energy resources – DER, e.g. generators, heat pumps, e-mobility)

Especially, a solution for the interaction of grid components by means of communication is developed. Thereby the power quality with a high amount of distributed energy resources and electric vehicles must be secured according to EN 50160 without any or at a minimum of grid reinforcement.

METHODOLOGY

Based on the experiences of previous projects in the medium voltage grid [5] and also low voltage grid [2][6], a suite of suitable control approaches is developed. These will be designed to allow a step-by-step extension from simple to more and more complex control strategies. The result of this work is described in this paper.
Subsequently, the control strategies will be evaluated in simulations. In order to gain precise results, a co-simulation environment is developed that can simulate both the electrical grid as well as the communication system that connects controller, remote sensors and actuators. The electrical grid model for selected test networks is validated using the ISOLVES-PSSA method [2][3].
After evaluation and test in simulations, real tests of solution approaches for central and distributed monitoring, management and control concepts in selected LV networks in Salzburg and Upper Austria will be performed. Actual voltage problems in selected low voltage segments are created by integrating a high share of PV and e-mobility (PV installation on every second roof, in the Salzburg test also electric car in every second house). In order not to exceed the limits for power quality, in the pilot regions stricter voltage limits are set than necessary. The previously developed control concepts will then be applied to solve the generated voltage problems and keep voltages

within the stricter limits.

OVERALL SMART CONTROL CONCEPT

The following figure shows the fife 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.

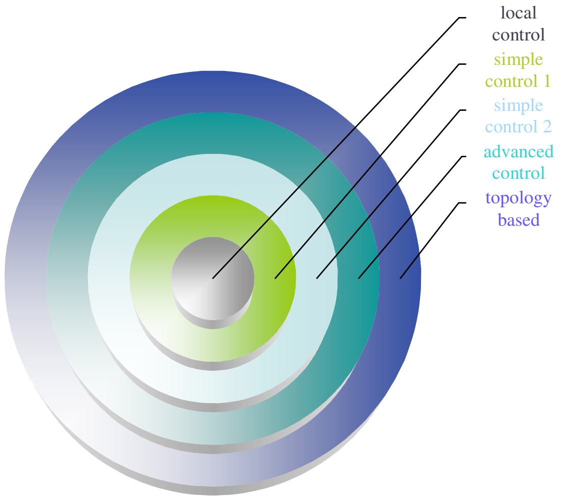

Figure 1: Fife stages of control concept

This structure takes into account the increasing complexity during development process. After verification of the functionality by co-simulation, based on models of LV grid 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) under real test conditions. With this procedure the concept can be demonstrated step by step in real LV grids. The findings after realization of each stage will be used to enhance the next stages.

Stage 1: "local control"

Local actuators like PV inverters [4], transformer 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 steps.

Figure 2: concept of stage 1

There is no communication between the LVGC and the mentioned "actors" of the system

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. Here, the communication infrastructure is used to get information of the actual voltage band violations to control the voltage level in the system. Additional distributed actuators like PV-inverters and e-mobility charging units are still in droop control mode like in stage 1.

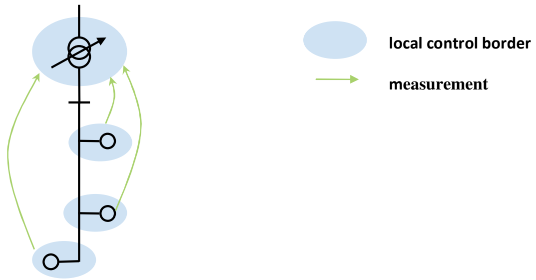

Figure 3: concept of stage 2

There is only a unidirectional communication from grid to the LVGC.

Stage 3: "simple control 2"

The next step 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 (e.g. reactive power for PV inverters) via broadcasts by LVGC. This approach can enable, that all PV inverters can feed in maximum of active power. Therefore 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 starts e.g. feeding in reactive power to increase the voltage.

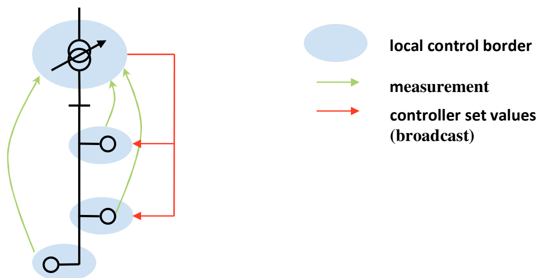

Figure 4: concept of stage 3

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

Stage 4: "advanced control"

To also enable 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.

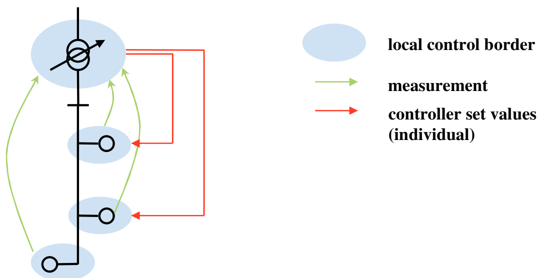

Figure 5: concept of stage 4

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

Stage 5: "topology based control"

This stage is based on the advanced control considering the information about actual topology of the network in the optimization. This will allow the find the global optimum in case there are dynamic changes of the network topology (e.g. due to shifting of sectioning point). This can be done by the additional installation of smart meter based "current guards" in all branches and selected nodes.

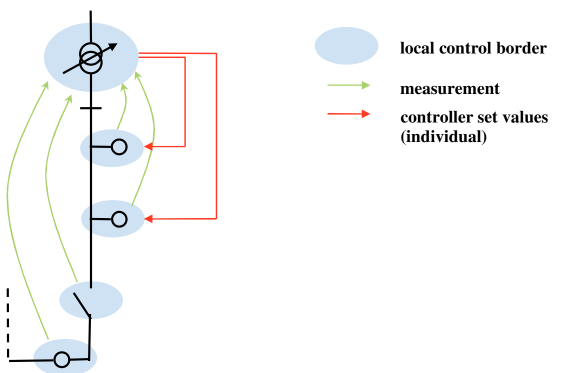

Figure 6: concept of stage 5

Moreover also intelligent algorithm for topology estimation bases on Power Snap Shot Analysis (PSSA) [2], [3] will be applied and tested under real conditions.

PILOT INSTALLATIONS IN THE PILOT REGIONS, THE «DEMO NETS»

The pilot regions were carefully selected by an assessment of the electrical low voltage infrastructure (number of nodes in the network, length of lines, possibility to supply from neighbouring networks) and the community (activity in energy efficiency programs etc). After the selection, information events for the residents of the selected municipalities were organised. For each of the three grid operators who have joined the project consortium, a pilot installation will be realised. In order to make efficient use of the three pilots, each has a specific focus.

Pilot 1 will target the topic of smart planning and smart monitoring. It will be critically analyzed in how far it makes sense to delay grid reinforcement with active grid operation approaches.

Pilot 2 will focus on high densities of PV. On every second roof of the demo region, PV will be installed. This capital-intensive process is financed by a mix of 1. regular governmental funding for PV installations, 2. additional funding by the grid operators and 3. own contribution of the homeowners, which itself is supported by the financing model from a local bank. Although it was seen as a very critical step in the project to succeed in finding enough homeowners in a dedicated area to participate in the field trial, these efforts were extremely successful and it turned out that there were more volunteers for the field test than required.

Pilot 3 is similar to pilot 2 in terms of the technology and recruiting process, however, it incorporates not only PV installations but also electric cars in every second house. Here, a leasing model is applied. During the field test, the leasing rate is backed by the grid operator with an option for the participator to keep the car with a higher rate after the trial. Also for the demo region of pilot 3, the recruiting process was highly successful.

OUTLOOK

The next steps in the project are to implement the developed control strategies in the co-simulation environment. After tests and improvements, the field test of the control strategies is planned to start in the first quarter of 2013.

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REFERENCES

[1] M. Stifter, B. Bletterie, H. Brunner, D. Burnier, A. Abart, F. Andren, s. Sawsan, R. Schwalbe, R. Nenning, F. Herb, R.Pointner, 2011," DG DemoNet Validation: Voltage Control: from Simulation to Field Test", *IEEE PES, ISGT Innovative Smart Grid Technologies Europe 2011*, 5-7 December 2011, Manchester, UK

[2] A. Abart, B. Bletterie, M. Stifter, H. Brunner, D. Burnier, A. Lugmaier, A. Schenk, 2011, "Power SnapShot Analysis: A new method for analyzing low voltage grids using a smart metering system", *21st International Conference on Electricity Distribution*, 6-9 June 2011, Frankfurt

[3] A. Abart, M. Stifter, B. Bletterie, H. Brunner, D. Burnier, R. Pointner, A. Schenk, R. Pitz, H. Taus, 2010, "Eyes to the grid: new ways to analyze electrical low voltage networks", *e&i Elektrotechnik und Informationstechnik*, Volume 128, Number 4, 122-127, DOI: 10.1007/s00502-011-0821-y

[4] B. Bletterie, A. Gorsek, A. Abart, M. Heidl, 2011, "Understanding the Effects of Unsymmetrical Infeed on the Voltage Rise for the Design of Suitable Voltage Control Algorithms with PV Inverters", *26th European Photovoltaic Solar Energy Conference and Exhibition*, 5-9 September 2011, Hamburg, Germany, Pages 4469 - 4478, ISBN 3-936338-27-2, DOI 10.4229/26thEUPVSEC2011-6DO.13.6

[5] A. Lugmaier, H. Brunner, B. Bletterie, F. Kupzog, A. Abart 2007, "Intelligent Distribution Grids in respect of a growing share of Distributed Generation," *in 19th International Conference on Electricity Distribution (CIRED 2007),"* Vienna, Austria, May 2007

[6] R. Witzmann, N. Grass, R. Keck, A. Adelmann, H. Hampel, M. Sebeck: „Netzstützung in Niederspannungsverteilnetzen durch intelligente Wechselrichter bei dezentraler Einspeisung", VDE-Kongress 2010, Leipzig, Paper IVN 4.4.1