European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**TEAM-VAR2**
Title	**Networked feedback control of distributed energy resources for real-time voltage regulation**
ERIGrid Reference	**04.018-2018**
TA Call No.	**4**

HOST RESEARCH INFRASTRUCTURE			
Name	**SYSLAB at Technical University of Denmark (DTU)**		
Country	**Denmark**		
Start date	**06/05/19 & 13/06/19**	**Nº of Access days**	**10**
End date	**17/05/19 & 24/06/19**	**Nº of Stay days**	**24**

USER GROUP	
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1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

Future power distribution networks will be characterized by distributed and intermittent microgeneration, charging facilities for a widespread electric mobility infrastructure, and increased overall demand subject to strict reliability specifications. Grid congestion is expected to occur increasingly often, and the operational constraints of the grid (e.g. over- and under- voltage limits) will become a bottleneck to the efficient implementation of this transition.

An extremely promising avenue consists in exploiting the electronic power converters available at every micro generator as a finely distributed network of reactive power compensators. If properly controlled, these devices have the potential of regulating the feeder voltage profile, increasing grid efficiency, and ultimately extending its hosting capacity without any structural reinforcement.

The project aims at validating a control approach that departs from both the traditional model-based optimization that is currently employed for the management of power systems, and from the simplistic, purely local, control strategies which have been recently proposed in the literature, and have even appeared in grid code drafts. It is a real-time feedback strategy, therefore robust against parametric uncertainty and unmodeled disturbances, and superior with the respect to dynamic control loop performance. Most importantly, it is a networked strategy, i.e., it enables coordination and cooperation between the different converters, in order to drive their operation to an optimal configuration in which all voltage constraints are satisfied.

The experiments proposed in this project have the potential of validating, in a proof-of-concept prototype, a two-fold fundamental claim:

1. Communication between converters is necessary for effective voltage regulation
2. Scalable distributed communication architectures are as good as centralized ones

These results have far-reaching implications, in terms of specifications for the design of smart distribution grid infrastructures. In line with ERIGRID goals, this project shows how it is possible (and necessary) to analyze and evaluate the complex interactions that emerge in these cyber-physical systems.

The whole investigation was organized into three sub-experiments.

Experiment 1 – Benchmark scenario

The goal of this experiment is to identify a benchmark, i.e., a grid topology so that, in the presence of typical generation and power demand patterns, under- and/or over- voltage phenomena are observed if reactive power is not controlled.

Experiment 2 – Suboptimal local Volt/VAR control

A set of local reactive power control algorithms was run in Experiment 2. The goal of this experiment is to validate the fact that purely local reactive power control policies (i.e. based on local voltage and reactive power measurements, without communication) cannot regulate the feeder voltage profile to the desired level, even if the problem is feasible (that is, there exist reactive power set-points for the power converters that achieve so).

Experiment 3 – Networked Volt/VAR control

The goal of this experiment is to show how a networked feedback control law, in which the reactive power injection of each converter is controlled based on both local voltage measurements and information coming from other converters, can perform practically as good as the benchmark ORPF solution.

Experiment 4 – Distributed networked Volt/VAR control

The goal of this experiment is to implement a distributed networked controller that controls the voltage without a central unit. It is supposed to show that communication between neighboring converters is sufficient to enable an optimal reactive power dispatch.

2. MAIN ACHIEVEMENTS (results, conclusions, lessons learned)

Multiple conclusions can be drawn based on the collected data:

Experiment 1 – Benchmark Scenario

- we identified a grid topology and corresponding active power production and consumption patterns that lead to overvoltages if the reactive power on the grid is not controlled;
- even in a relatively simple and small distribution feeder, power generation from renewable sources (wind and solar) may need to be curtailed because of overvoltage contingencies if reactive power is not used;

Experiment 2 – Suboptimal local Volt/VAR control

- as predicted, purely local controllers can barely mitigate this problem; the reactive power capability of the generators that experience overvoltage are generally limited and insufficient to regulate the voltage;
- local controllers can make the overvoltages worse leading to an even higher curtailment of renewable power infeed;

Experiment 3 – Networked Volt/VAR control

- model-based approaches, based on the centralized solution of an ORPF problem, has limited applicability because of the model uncertainty and measurements errors;
- networked solutions exhibit the cooperative behavior that was expected, therefore unleashing the full potential of a distributed network of reactive power compensators;
- the networked controller is very robust and needs nearly no model information, which enables a plug and play rollout to the power grid;

Experiment 4 – Distributed networked Volt/VAR control

- a distributed implementation without a central unit was implemented and performed well;
- triggered by the physical experiments we numerically analyzed the scalability of the control approach. It scales well with the number of inverters on the grid;
- furthermore, we found out that one should perform as many communication steps in between actuations steps as possible;

3. PLANNED DISSEMINATION OF RESULTS (journals, conferences, others)

Using the results obtained with the data that we gathered during the research stay we submitted two papers to the conference Power Systems Computation Conference 2020.

L. Ortmann, A. Hauswirth, I. Caduff, F. Dörfler, S. Bolognani
"Experimental Validation of Feedback Optimization in Power Distribution Grids",
Power Systems Computation Conference 2020
https://arxiv.org/abs/1910.03384

L. Ortmann, A. Prostejovsky, K. Heussen, S. Bolognani
"Fully distributed peer-to-peer optimal voltage control with minimal model requirements"
Power Systems Computation Conference 2020
https://arxiv.org/abs/1910.03392

4. PLANNED DISSEMINATION OF RESULTS THROUGH ERIGRID CHANNELS

Contact erigrid-ta@list.ait.ac.at to organise promotion of your results

We will provide the information for the TA Success Story section on the ERIGRID website.