TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**TEAM-VAR**
Title	**Networked feedback control of distributed energy resources for real-time voltage regulation**
ERIGrid Reference	**01.001-2016**
TA Call No.	**1**

HOST RESEARCH INFRASTRUCTURE			
Name	**SYSLAB at Technical University of Denmark (DTU)**		
Country	**Denmark**		
Start date	**08.10.2017**	**Nº of Access days**	**28**
End date	**05.11.2017**	**Nº of Stay days**	**29**

USER GROUP	
Name (Leader)	**Saverio Bolognani**
Organization (Leader)	**ETH Zurich**
Country (Leader)	**Switzerland**
Name	**Adrian Hauswirth**
Organization	**ETH Zurich**
Country	**Switzerland**
Name	**Ivo Caduff**
Organization	**ETH Zurich**
Country	**Switzerland**
Name	
Organization	
Country	

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 analyse 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.

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

Multiple conclusions can be drawn based on the collected data:

- 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, especially when the grid is not loaded;
- the fluctuating voltage at the point of connection to the MV grid introduces the need for relatively fast-tracking performance in the voltage regulation problem;
- 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;
- 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 behaviour that was expected, therefore unleashing the full potential of a distributed network of reactive power compensators;
- parameter tuning of the networked controllers proved to be more challenging than their purely local counterparts, and to be a practical impediment to a plug-and-play deployment of this control solution.

The following natural follow-up experiment is anticipated.

- The implementation of the distributed/networked control strategies was done at a central location, and therefore simulated. This architectural solution had the obvious advantage of allowing quick debugging and testing, complete monitoring, and fast prototyping. On the other hand, the complexity coming from a true distributed implementation (peer-to-peer communication, among others) is hidden. A full analysis of this aspect is only possible by implementing a true distributed control strategy, where each agent (DER) runs independent pieces of code locally, and communicate in a peer-to-peer fashion to the other DERs. A central local shall only be used for monitoring and logging purposes.

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

Following the completion of the analysis of the collected data, the following dissemination activities are planned.

- **Technical report** – A technical report containing the documentation of the experiments and the results, complete with a data repository, will be made available in an open-access self-archiving platform.
- **Scientific publications –** We expect to publish the results of these experiment in the following ways:
  - as a contribution to a journal paper currently under preparation, where the mathematical aspect of the problem under study is presented and analysed
  - as a conference contribution where the key finding of the experiment are presented and discussed

- based on the quality of the collected data, and ideally via a follow-up experiment that could resolve the aforementioned open issues, as a journal article.

- **Benchmark** – The scenario that we identified in the experiment will be shared in order to provide the research and industrial community with a simple tractable example where purely local control strategies are provably suboptimal and ineffective.
- **Grid simulator** – The grid simulator for SYSLAB will be made available to the research infrastructure, and made public to those researchers that want to replicate the proposed benchmark scenario and validate their own Volt-VAR controllers.