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"Laboratory Evaluation of a Deterministic Optimal Power Flow Algorithm using Power Hardware in the Loop"

Abstract. The development of new technologies in the areas of energy generation, power electronics and ICT are enabling smart grids. Moreover, high penetrations of distributed generation are very promising from the point of view of reducing CO2 emissions but pose a number of challenges and opportunities in the economic development of future grids. Furthermore, the effective distribution of energy is key to efficient utilization of electrical energy and thus reduction of the overall CO2 footprint.

The objective of this work is to evaluate centralized voltage optimization algorithms from a perspective of future distribution network with high penetrations of Distributed Generation (DG) using a laboratory featuring Power Hardware-in-the-Loop (PHiL) technology. This will enable practical evaluation of state-of-the-art voltage control equipment in future challenging network scenarios using PHiL. Oriented Discrete Coordinate Descent Method (ODCDM) optimization algorithm was chosen as an exemplar of a centralized voltage control of a real distribution network as it has been shown to be robust and reliable when implemented in real distribution networks [1]. In this study, transformers equipped with On Load Tap Changers (OLTCs), Energy Storage Systems (ESSs) and Mechanically Switched Capacitor Banks (MSCs) are used to control voltages. The ODCDM based voltage control method is contrasted with conventional, distributed, passively coordinated voltage control approach.

Previous work has shown that ODCDM based voltage control algorithm has a short computation speed, high reliability and excellent convergence properties [2]. As such, this work is focussed on the resolution of voltage issues in real-time. Thus, the main mathematical problem is formulated as minimum objective function of real power network losses. To keep voltage levels and control variables within statutory limits a penalty function is included within optimization objective function.

The case study network in this work is based on an existing distribution network in the northeast of England and owned by Northern Powergrid. This network comprises OLTC transformers, ESSs and MSCs. A wind farm and photovoltaic (PV) DGs are added to this network in order to investigate scenarios of future distribution network featuring large concentrations of DG and Low Carbon Technologies (LCT) in extreme conditions (high winds, high level of solar radiation and heavy load).

To enable this investigation a real-time trial for 24 hours under extreme conditions was carried out. The network model, in conjunction with high temporal resolution load, wind and PV data, will be used with the laboratory and the PHiL technology to carry out this trial. Identical conditions in the trial were used to compare the capability of ODCDM voltage control of OLTC transformers, ESSs and MSCs with distributed voltage control of OLTC transformers, ESSs and MSCs. This enables understanding of the capability of next generation centralized voltage control approaches, based on Optimal Power Flow (OPF), in comparison with conventional, passively coordinated approaches to voltage control. The evaluation approach proposed in this work, uses real smart grid components under challenging network conditions in contrast to previous approaches where the smart grid components and network are simulated using idealized versions of the smart grid elements.

References

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Bio. Received Bachelor's degree in the field of Automation and Control from Tomsk Polytechnic University, Institute of Cybernetics in 2011. During the undergraduate education, spent 1 term studying in Czech Technical University in Prague, department of Cybernetics as a part of international exchange program. Did his BSc internship in Robotics laboratory in Technical University of Munich. Received Master's degree in the field of Control in Technical Systems from Saint-Petersburg State Technical University, department of Automatic Control Systems in 2013. Did his MSc internship in Nissan manufacturing plant in UK. Has 3 years of working experience in the field of automation, telecommunication and SCADA-systems development for electrical energy distribution purposes. His PhD research interest is control in terms of Smart Grids and Microgrids.