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Tutorial Title:

Virtual Synchronous Machines - Inverters for a Stable and Well-damped Grid

Organizer:

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Abstract:

The current shift from fossil-based energy production towards renewable power in the electric grid, as well as the integration of Battery Storage Systems (BSS) and the bidirectional V2G, are radically challenging the power grid due to the proliferation of static power converters (inverters). Without new approaches to inverter control, the associated drop in overall system inertia and damping decreases and deteriorates the grid's stability and robustness against disturbances and faults.

A promising solution to this challenge is the Virtual Synchronous Machine (VSM): inverters behaving like synchronous generators to provide grid services and grid support. Therefore, the VSM-controlled inverters can contribute to system inertia, damping and the decentralized regulation of voltage and frequency. Moreover, their very fast response time, and their ease of reprogramming to add new features in their control algorithm, opens ways to improve their performance beyond what is possible with synchronous generators.

This tutorial will start presenting requirements for safe grid operation and stability requirements that impose bounds on damping and inertia from the power electronics perspective. Then, the concept of VSM will be presented and its advantages compared to other control strategies are highlighted.

We analyze the performance of a microgrid comprising VSMs in island mode as well as when connected to a main grid. We also consider microgrids comprising both VSM and synchronous machines and show the interdependence between system parameters, VSM parameters and the physical equipment of the inverter. Finally, we introduce more advanced concepts for the safe and stable operation of VSMs: the influence of measurement errors and grid voltage distortions, black start mechanisms and ways to improve the damping of oscillations and fault ride-through using communication links between inverters.

Bio:

Radu Bojoi received the M.Sc. degree from Technical University of Iasi, Romania, in 1993, and the Ph.D. degree from Politecnico di Torino, Torino, Italy, in 2002, all in electrical engineering. He is a Full Professor of Power Electronics and Electrical Drives with the Energy Department G. Ferraris and Chairman of the Power Electronics Innovation Center, Politecnico di Torino. He has authored or coauthored more than 150 papers covering electrical drives and power electronics for industrial applications, transportation electrification, power quality, and home appliances. He was involved in many research projects with industry for direct technology transfer aiming at obtaining new products. Prof. Bojoi is the co-recipient of five prize paper awards, the last one in 2015 as IEEE-IAS Prize Paper Award. He is teaching several courses in the area of power electronics and power systems, and has given tutorials in ICEM 2018, ECCE 2018 and IEMDC 2019.

Fabio Mandrile received the M.Sc. and Ph.D. degrees in electrical engineering from Politecnico di Torino, Italy, in 2017 and 2021, respectively. He is currently assistant professor at Dipartimento Energia G. Ferraris at Politecnico di Torino. His main research interests are virtual synchronous machines and power electronics for grid-connected applications, on which he focused his Ph.D. and current research activity.

George Weiss received the M.Eng. degree in control engineering from the Polytechnic Institute of Bucharest, Romania, in 1981, and the Ph.D. degree in applied mathematics from Weizmann Institute, Rehovot, Israel, in 1989. He was with Brown University, Providence, RI, USA; Virginia Tech, Blacksburg, VA, USA; Ben-Gurion University, Be'er Sheva, Israel; the University of Exeter, U.K.; and Imperial College London, U.K. He is leading research projects of the European Commission, the Israeli Ministry of Energy and the Israeli Electricity Company. His research interests include distributed parameter systems, operator semigroups, passive and conservative systems, power electronics, repetitive control, sampled data systems, and wind-driven power generators. He teaches courses from the general area of control theory, functional analysis and power electronics, and has given tutorials and plenary lectures at several conferences.

Florian Reissner received the B.Sc. and M.Sc. degrees from the Technical University of Berlin, Germany, in 2015. He is currently pursuing the Ph.D. degree with the Power Electronics for Renewable Energy Group, Tel Aviv University. From 2015 to 2020, he worked in project management with Vinci Energies, Lyon, and he was an Innovation Consultant and design thinking coach with incubators in Frankfurt and Berlin. In 2020, he started working as an Early Stage Researcher (funded by the European Commission) at Tel Aviv University. His current research interests include control techniques in power systems and control theory.