DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

PhD Public Defence

Title:	Multi-Functional Distributed Secondary Control for Autonomous Microgrids
Location:	Pontoppidanstræde 101, Room 23
Time:	Thursday 4 December 2014 at 13.00
PhD defendant:	Qobad Shafiee
Supervisor:	Professor Josep Maria Guerrero Zapata
Moderator:	Associate Professor Tamas Kerekes
Opponents:	Associate Professor Dezso Sera, Dept. of Energy Technology, AAU (chairman) Associate Professor Giancarlo Ferrari Trecate, Dipartimento di Informatica e Sistemistica, Universita' degli Studi di Pavia, Italy Associate Professor Ramon Blasco-Gimenez, Universidad Politécnica de Valencia, Spain

All are welcome. The defence will be in English.

After the public defence there will be an informal reception in Pontoppidanstræde 101 room 25/27.

DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Abstract:

Microgrids (MGs)--the building blocks of the smart grid-- are local grids comprise different technologies such as power electronics converters, distributed renewable and non-renewable energy sources, energy storage systems, and telecommunications which can operate either in islanded mode or connected to the main grid. Apart from the obvious benefits of MGs, their introduction into the traditional distribution network raises many new challenges, thus, a hierarchical control concept has been introduced for these systems. While the decentralized primary control of this hierarchy ensures the system stability and adjusts the frequency and voltage according to the active and reactive powers, the secondary control level is often used to regulate the system frequency and voltage to the rated values, eliminating deviations produced by primary level. The tertiary control is in charge of regulating power exchange with external grid or/and with other MGs and includes functions related to efficiency and economic enhancement.

This thesis is focused on development of distributed control strategies for secondary control of autonomous ac and dc MGs to avoid a central controller and complex communication network, thus offering improved reliability and expandability. The special emphasis has been given to consensus-based protocols where the mathematical analysis has been also studied and presented. The proposed methodologies based on this approach are fully distributed meaning that each MG source requires exchanging information with only its direct neighbors through a sparse communication network. Loss of sources and communication links do not affect system operation as long as the communication graph remains connected. Moreover, they are scalable, for that prior knowledge of the system is not required, as a new component enters the MG. The proposed control frameworks for ac MGs include three modules, namely, frequency and active power sharing regulator, voltage regulator, and reactive power regulator. The first module addresses frequency synchronization without using any frequency measurement, which improves the system dynamic. The voltage regulator boosts the voltage across the MG to satisfy the global voltage regulation, while the reactive power regulator handles the proportional reactive power sharing considering transmission line impedances. Moreover, the proposed controllers are able to proportionally share the load power even at the presence of different control parameters and initial values.

This thesis also proposes a distributed hierarchical control framework for dc MG clusters to ensure smooth connection and reliable operation of these systems. A decentralize adaptive droop method is introduced for primary control level which determines droop coefficients according to the state-of-charge (SOC) of batteries automatically. Then a small signal model is developed to investigate effects of the proposed method parameters and the system parameters on the stability of these systems, as well as to tune the control parameters. Finally, a consensus-based distributed control framework is proposed which provides all features of distributed control methods. It eliminates the average voltage deviation over the MGs while regulating the power flow control between the MGs according to their local SOCs at the same time. The proposed approach only needs neighbor-to-neighbor communication through a spars communication infrastructure.

Experimental and simulation studies are presented to demonstrate the application and effectiveness of the proposed strategies in different scenarios.