Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
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PhD information	
Title	Power Quality and Stability Enhancement in Distributed Generation Systems based Microgrids
Main topics regards to CSC list (3 topics at maximum)	I-17. Control theory and technique VI.-2. Prevention of serious engineering safety breakdowns and system safety

Required skills in science and engineering	Electrical Engineering - Control theory - Power electronics

Subject description (two pages maximum)

Context:

Today's energy transition challenges make the emerging of innovative Smart Grid concepts as the main solution to meet with numerous environmental, techno-economic, and energy-security requirements. These concepts encourage on-site generation based on low-emission energy technologies and a high share of locally available Renewable Energy Sources (RESs) and Energy Storage Systems (ESSs). Indeed, the deployment of Distributed Generation (DG) based Microgrids (MGs) is the key to secure the transition towards future Smart Grids. These systems can operate close to end-users with either grid-connected or islanded mode, which improves local grid reliability and resilience, increases energy efficiency and bring additional benefits regarding investment reduction for future grid reinforcement and expansion. However, this concept remains subject to many concerns essentially in islanded mode of operation where power quality and stability issues characterized by an increase of both voltage waveform unbalance and harmonic distortion can be noticed due in part to load disturbances and RESs intermittency. In addition, these systems can experience undesired resonance phenomena owing to their potential unstable dynamic, which can weaken their performances and even lead to instability. In this way, this project will address these emerging and challenging issues based on innovative control techniques that will have to secure both power quality and stability requirements in multiple DG based islanded MGs.

Thesis Goals

The control of Microgrids with several DG usually adopts a hierarchical control structure with primary, secondary and tertiary control levels, encompassing voltage and current control loops, active and reactive power sharing control loops, voltage and frequency restoration loops and also power flow control loops with synchronization and islanding detection algorithms. The resulting control scheme achieves satisfactory performances, but remains faced to major issues related to the presence of interconnecting passive filters with recurrent resonance phenomena and the proliferation of nonlinear and unbalanced loads. These system configurations are prompt to experience resonance phenomena, which will ineluctably reduce power quality and weaken their global stability.

The proposed project is intended to address both power quality and stability issues in DG based islanded MGs. More specifically, this project will provide useful tools to investigate and fix resonance phenomena encountered in islanded MGs with multiple electronically interfaced DGs and loads.

The first goal is the investigation of the resonance characteristics of islanded MGs based on the development of a comprehensive MG modeling that describes accurately the dynamic behavior and the main resonance interactions of the interconnected DGs and loads. In this way, a systematic modeling approach will be proposed based on the equivalent representations of the interconnected DGs and

Loads. The obtained mathematical model will be then analyzed based on small signal and large signal tools in order to determine the system stability region.

The second goal is the design of an advanced active damping method is preconized to cope with resonance phenomena and improve the local and global stability of islanded MGs. Indeed, an additional control level dedicated to resonance active damping will be incorporated together with the conventional hierarchical control structure of each DG unit in order to limit both resonance harmonic amplification and propagation in islanded MGs. Among the potential techniques, the globally convergent observers have the ability to damp periodic signals with time varying frequencies and amplitudes and present numerous advantages being frequency-independent and robust against amplitude uncertainties even in presence of distorted sinusoid signals with multiple sinusoids of different frequencies. In this project, these methods will be exploited for the synthesis of robust disturbance observers that act as resonance compensators. The use of advanced automatic techniques, such as the generalized circle criterion and the contraction theory is envisaged for the observers design purpose. Therefore, even if the system is moved far from its steady state operating point after a large resonance interaction, we can prove that all states will converge asymptotically to their new operating equilibrium points. The proposed techniques should be able to fix both transient and steady-state resonance disturbances for harmonic and sub-harmonic frequencies independently of system configuration, which will certainly sustain the plug & play characteristic of the interconnected DGs and secure safe and stable operation of MGs.

The proposed control techniques will be supported thorough theoretic analysis and experimental tests.

Planning

Four work steps will be necessary to carry out the stated research goals and disseminate the important findings.

Step 1 (6 months): State of the art.

Step 2 (14 months): Methodologies development.

- Design of a comprehensive model of MGs.
- Theoretic analysis of the MG stability.
- Design of robust stabilizers to mitigate resonance instabilities in islanded DG based MGs.
- Dissemination of partial results

Step 3 (10 months): Experimental evaluation of the developed algorithms under various scenarios. The use of the IREENA’ Smart Power platform that corresponds to a small residential Microgrid including DGs and numerous household loads is preconized.

Step 4 (6 months): Dissemination of results and redaction of the thesis report.

References

1 Colmenar-Santos, Antonio, et al. "Distributed generation: A review of factors that can contribute most to achieve a scenario of DG units embedded in the new distribution networks." Renewable and Sustainable Energy Reviews 59 (2016): 1130-1148.

2 Saim, Abdelhakim, et al. "Adaptive resonant based multi-loop control strategy for parallel distributed generation units in standalone microgrid application." Electric Power Systems Research 143 (2017): 262-271.

3 Vasquez, Juan C., et al. "Hierarchical control of intelligent microgrids." IEEE Industrial Electronics Magazine 4.4 (2010): 23-29.

4 Youssef, Karim Hassan. "Power Quality Constrained Optimal Management of Unbalanced Smart Microgrids During Scheduled Multiple Transitions Between Grid-Connected and Islanded Modes." IEEE Transactions on Smart Grid 8.1 (2017): 457-464.

5 Wang, Xiongfei, Frede Blaabjerg, and Zhe Chen. "Autonomous control of inverter-interfaced distributed generation units for harmonic current filtering and resonance damping in an islanded microgrid." IEEE Transactions on Industry Applications 50.1 (2014): 452-461.
6 He, Jinwei, et al. "Investigation and active damping of multiple resonances in a parallel-inverter-based microgrid." IEEE Transactions on power Electronics 28.1 (2013): 234-246.
7 Wang, Xiongfei, et al. "An active damper for stabilizing power-electronics-based AC systems." IEEE Transactions on Power Electronics 29.7 (2014): 3318-3329.
8 Houari, Azeddine, et al. "Large-signal stabilization of ac grid supplying voltage-source converters with LCL-filters." IEEE Transactions on Industry Applications 51.1 (2015): 702-711.