PhD Proposal 2017

School: Ecole Centrale de Lille	
Laboratory: L2EP	**Web site: http://l2ep.univ-lille1.fr/**
Team: Equipe Réseaux	**Head of the team: Benoit ROBYNS**
Supervisor: Bruno FRANCOIS	**Email: bruno.francois@ec-lille.fr**
Collaboration with other partner during this PhD: 0	**In China:**

Title: Stability analysis of Grid forming with an Energy Storage System for sustainable development of electrical networks
Scientific field: Electrical Engineering
Key words: Power systems, renewable energy, storage, rms voltage control, frequency control, modeling, energy management, grid forming

Details for the subject:

Diesel hybrid autonomous power systems present good potential for creating remote electrical grids. Fuel consumption and emissions can be reduced by the use of Renewable Energy Sources (RESs) such as photovoltaic (PV) and wind. In isolated off-grid hybrid power systems with a high penetration of renewable energy (wind, solar, etc.), experience has shown that electric energy storage, typically batteries, can greatly reduce the portion of the load that must be met with traditional fossil fuel based generation. With a Battery Energy Storage System (BESS), power generation and consumption can be decoupled allowing further reductions in fuel consumption.

Even relatively short term energy storage (15-20 minutes at average load) significantly increases the amount of time that the system can be operated purely on renewable sources and helps to ensure continuous and reliable power delivery. In fact, while a typical high penetration wind-diesel system might achieve 40- 50% fuel savings, the same system with the addition of energy storage could achieve fuel savings of 70-80%.

In order to perform these fuel savings, it is essential that the system is designed such that the conventional generators (e.g. diesel gensets) can be turned off.

Then the load is supplied by the RESs and BESS. In this case, the latter has to form the grid, regulating voltage and frequency.

However, most commercial and industrial scale wind turbines and solar photovoltaic inverters are designed to be grid-connected. They cannot operate unless connected to an AC power system with a well regulated voltage and frequency. Voltage and frequency regulation on a micro-grid is a role normally played by the conventional generation equipment, typically one or more diesel generators. Thus, the challenge for a high penetration renewable energy system is to provide good frequency and voltage regulation even during periods when the conventional generators are shut off.
Regulating frequency is essentially a matter of maintaining an instantaneous balance of real power (kW) in the system at all times, while voltage regulation involves maintaining an instantaneous balance of reactive power (kVAR) at all times. These two functions together are sometimes referred to as *grid forming*.

Research subject, work plan:

The proposed research project consists in the power system analysis in steady state but also in transient state of an isolated electrical network powered by synchronous generator based wind generators. The grid forming function will be provided by a battery storage. The issue is to develop a theoretical algorithm for the seamless cooperation of generation and batteries. The target is to demonstrate how energy storage can allow high renewable energy penetration levels and maximum fuel savings. Tests of a BESS interface providing regulated balanced voltages under various demanding load conditions will be experimented in the laboratory.
The scheduled roadmap is:

1) to master and improve available models of various electrical equipment, that enable the operation of a network (AC cables, DC cables, transformers, power electronic conversion station, …),
2) to consider the implementation of a storage system (modelling and control),
3) to simulate the entire power systems and evaluate performances and interests,
4) to analyse the stability of this power system.

Skills

- Knowledge in electrical engineering and in operating of power systems (electrical networks),
- Knowledge in control theory and dynamics theory,
- Motivation for practical works and applications,
- Simulation software: Matlab / Simulink,
- English or French language

References:

[1] B. Robyns, B. Francois, G. Delille, C. Saudemont, " Energy Storage in Electric Power Grids", Wiley, 2015, ISBN: 978-1-84821-611-2.

[2] P. Mahat, J. Escribano Jiménez, E. R. Moldes, S. I. Haug, I.z G. Szczesny, K. E. Pollestad, L. C. Totu, „A Micro-Grid Battery Storage Management", 2013 IEEE Power and Energy Society General Meeting (PES). IEEE Press, 2013

[3] D. Colin, J. Lugaro, J.-C. Pinna, G. Delille, B. Francois, C. Caton, G. Martin, "The VENTEEA 2MW/1.3MWH Battery System: An Industrial Pilot to Demonstrate Multi-Service Operation of Storage in Distribution Grids", 23rd International Conference on Electricity Distribution, CIRED 2015, Lyon, 15-18 June 2015.

[4] H. Dutrieux, G. Delille, G. Malarange, B. Francois, "An Energy Supervision for Distributed Storage Systems to Optimize the Provision of Multiple Services", IEEE PES International Conference Powertech, 16-20 June 2013, Grenoble, France.

[5] G. Delille, B. Francois, "A review of some technical and economic features of energy storage technologies for distribution systems integration", Ecological Engineering and Environment Protection, No1, p. 40-49, ISSN 1311-8668, 2009.

[6] S. A. Amamra, B. Francois, "Day-ahead Primary Power Reserve Planning and Day-D Primary Frequency Control of a Li-Ion Battery", IEEE PES International Conference Powertech, 2015, Eindhoven, 29th June - 2nd July

[7] H. Kanchev, F.Colas, V. Lazarov, B. Francois, Emission reduction and economical optimization of an urban microgrid operation including dispatched PV-based active generators, IEEE Trans. On Sustainable Energy, Vol. 5, No. 4, Oct. 2014, pp. 1755-1796

[8] B. Robyns, A. Davigny, B. Francois, A. Henneton, J. Sprooten, "Electricity Production from Renewables Energies", Wiley, 2012, ISBN 978-1-84821-390-6.