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

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PhD information	
Title	Strategies for Optimal Management of a micro-grid integrating storage and distributed renewable energy sources
Main topics regards to CSC list (3 topics at maximum)	I-17: Control theory and technique V-1: Prevention and treatment of electric system breakdowns. Economic process VI-2: Prevention of serious engineering breakdowns and system safety

Required skills in science and engineering	-Electrical engineering,- Control theory

Subject description (two pages maximum)

Nowadays, the electric grid management is centralized and unidirectional. Tomorrow, it will be decentralized and bidirectionnal. This new concept leads to a dramatic change in the way people will design and control the grid. That is why electric grids are in constant mutation and are heading towards more smartness to ensure objectives whilst dealing with constraints for nearly two decades. These objectives are: integration of renewable energy (RnE), balance management for supply and demand taking into account market mechanisms, reduction of greenhouse gases (GHG), energy efficiency improvements, security of energy supply for the consumer. Thus, the current grid is designed for centralized power plants providing energy to loads that have predictable behaviour. It will not be the case anymore in the future. The important share of RnE sources and their intrinsic intermittency will force grid operators to redesign the grid. There are two solutions: massive reinforcement of the actual grid or going towards smart grid solutions. The first one will cost a lot of money and is not very suitable for the deployement of RnE-based distributed generation (DG) units. Besides, the penetration of RnE will increase power quality needs and smart micro-grids (MGs) are a good answer for that because they can enable local control of: their loads, the frequency, the voltage as well as a rapid response of their storage system if they have any.

Smart grids integrate Information and Communication Technologies (ICT). This communication between stakeholders allows the smart grid to take into account everyone's actions (even the consumers). The aim is to ensure balance between supply and demand at all times. Reactivity, reliability and grid optimization are key features of smart grids. To make grids smarter, grid operators will have to increase their communication ability.

A smart MG is a self-sustaining cluster of distributed energy resources (DER) and loads that operates as a whole control entity in both grid-connected and off-grid modes. This concept appeared in the literature in 2001 [1]. Its loads can be fixed or flexible. It is able to provide both power and heat to the area where it is implanted (if there is a Combined Heat and Power unit) and its electrical boundaries are clearly defined. Ancillary services and load management are also key applications for a smart MG, thus it has an Energy Management System (EMS) which performs data aggregation and deliver control order to the connected electrical devices. These components are: smart switches, protective, control and communication devices as well as automation systems. The MG has also an Energy Storage System (ESS) such as a set of batteries or supercapacitors that acts in coordination with DG units to ensure stability and supply loads seamlessly in case of islanding. ESS can also be used for economical applications like energy arbitrage (buy low, sell high...) [2].

In parallel with the multiple advantages of this type of generation, complex scientific obstacles have to be solved to ensure efficient management while guaranteeing a good quality and a cost-competitive electricity produced over a given period of operation (25 years for example). Regarding efficiency, the uncertainties of the production of renewable sources and consumption can cause major difficulties in the planning and control of the MG. This imbalance between demand and production can lead to interactions that can lead to instability of the MG and/or electrical load-shedding of some consumers. In operating profitability terms, the weak link is the longevity of the storage elements. Excessive charge and discharge profiles can lead to accelerated storage aging which may require several replacements over a given system life. On way to deal with these constraints is to deploy a control hierarchy. This hierarchy involves primary, secondary and tertiary control [3]. Primary control deals with system variables (voltage and frequency) and makes sure they track their set points. It does not require communication abilities with other devices. Besides tracking set points, islanding detection and management of controller modes belongs to the primary control [4,5]. Central control or EMS belongs to secondary control. Secondary control deals with power quality and mitigates deviations thus it computes and determines optimal set points for the primary control. Tertiary control is focused on long-term stability and will use data from DER, market signals from energy exchanges, weather forecast and so on to ensure MG power requirements. Unlike primary control, both secondary and tertiary control can be implemented with central or distributed techniques.

The project of this thesis aims to propose multi-criteria management strategies and to study their performances. The objective is to optimize energy transfers within the MG, while taking into account the production-consumption uncertainties and integrating the aging aspect of the storage elements. The main challenges to be overcome are related to abrupt changes in operating conditions and communication delays that can reduce management efficiency and lead to operating imbalances. In this work, the performance of management techniques using meta-heuristic optimization algorithms, such as Grey Wolf Optimizer (GWO) [6] and Particles Swarm Optimizer (PSO), are to be developed. These algorithms will have to be flexible enough to respond to rapid changes in operation. Add to this, observation techniques will be used to mitigate the harmful effects of communication delays. This thesis work will also evaluate the management strategies developed in terms of minimizing the cost of the energy produced, carbon emission reduction and improving the longevity of the storage elements over a representative operating period (eg 25 years). The focus will be placed on evaluating aging of storage elements on representative use patterns. Techniques for estimating the lifetime of storage elements based on predictive algorithms will be investigated.

To carry out this work we must develop fine modeling techniques of the micro-grid based on the theory of hybrid dynamic systems [7] as well as the use of multi-agent systems [8]. The developed algorithms will be validated firstly through Matlab simulator and then tested on the IREENA laboratory smart-grid test bench.

References:

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[5] R. Vincent, **M. Ait-Ahmed**, A., Houari, M.F. Benkhoris, “Microgrid modeling and power quality enhancements using low-level control methods based on robust RST controller”, IECON 2018, The 44th Annual Conference of the IEEE Industrial Electronics Society, Washington DC, USA, October 21-23, 2018.

[6] A. Djerioui, A. Houari, **M. Ait-Ahmed**, M.F. Benkhoris, A. Chouder, M. Machmoum, “Grey Wolf based control for speed ripple reduction at low speed operation of PMSM drives”, ISA Transactions, V. 74 pp. 111-119, 2018.

[7] R. Goebel, R.G. Sanfelice, A.R. Teel, “Hybrid Dynamical Systems, Modeling, Stability and Robustness”, Princetown Universtity Press, 2012.

[8] R. Olfati-Saber, J.A. Fax, and R.M. Murray, “Consensus and cooperation in networked multi-agent systems”, Proceedings of the IEEE, 95(1):215-233, 2007.