Intelligent and Robust Control Strategy for Improving Microgrids Operation and Stability

by

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Certificate of Original Authorship

I, *Mohsen ESKANDARI* declare that this thesis is submitted in fulfilment of the requirements for the award of *Doctor of Philosophy (Ph.D.)*, in the *Faculty of Engineering and Information Technology, School of Electrical and Data Engineering* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Signature:

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and the God of the lofty throne
and the God of roaring sea
and the sender of the Bible and the Psalms
and the God of shadow and hot sun
and the sender of great Quran
and the God of esteemed angels, and prophets, and apostels…

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Nomenclature

Global abbreviations used in this thesis

CB	=	Circuit Breaker
CL	=	Common Load
CM	=	Connected Mode
CRF	=	Common Reference Frame
CSI	=	Current Source Inverter
DG	=	Distributed Generation
ESS	=	Energy Storage System
FIS	=	Fuzzy Interface System
FPSO	=	Fuzzy Particle Swarm Optimization
IIDG	=	Inverter Interfaced Distributed Generation
IM	=	Islanded Mode
LBWCL	=	Low Band-Width Communication Link
LMI		Linear Matrix Inequality
LQR	=	Linear Quadratic Regulator
LV	=	Low Voltage
MG	=	Microgrid
MGCC	=	Microgrid Central Controller
MS	=	Micro-source
NMG	=	Networked Microgrid
OVR	=	Optimal Voltage Regulator
RF	=	Reference Frame
PCC	=	Point of Common Coupling
PN	=	Power Network
RES	=	Renewable Energy Resources
S-VSI	=	Servo-Voltage Source Inverter
VSI	=	Voltage source Inverter

Abstract

The rising world-wide trend toward developing clean and efficient energy resources has caused dispersed installation of distributed generation (DG) units in power systems. Microgrid (MG) concept is considered as the best solution to address the resiliency issue of future modern power systems, which are expected to receive a considerable amount of power through inverter-interfaced DG (IIDG) units. Droop control systems are widely adopted in conventional power systems and the decentralized droop-like control method is the most favorable control system for MGs. However, there are some crucial issues related to the poor performance of droop control in autonomous networked MGs (NMGs), which are considered and addressed in this thesis.

The requirement of expensive and unreliable high band-width communication infrastructure is obviated in droop control. To this end, the power network is regarded as a communication link and voltage variables as control signals. This, however, reduces the stability margin of autonomous NMGs due to the interaction of droop controllers through the power network. Lack of inertia of droop-controlled power converters and low X/R ratio of interconnecting power lines intensify this interaction which may lead to the instability of NMGs. On the other hand, the existing parallel-based small-signal model of MGs is inadequate to represent this interaction in the content of NMGs. To this end, an accurate

state-space model is developed in a fully decentralized approach for autonomous NMGs which does not rely on any converter for any specific role.

Moreover, the major challenges related to NMG control is the ineffectiveness of droop control in accurate power-sharing, frequency fluctuations, and voltage deviation, which raise stability and power quality issues. This work also deals with frequency fluctuation and stability concerns of *f-P* droop control loop as well as dynamic performance, voltage regulation and stability concerns of *V-Q* control loop in autonomous NMGs.

Besides, penetration of IIDG units puts the stability of modern power systems into risk due to the vague and arbitrary output impedance of IIDG units. In this regard, an optimal voltage regulator (OVR) is proposed for controlling IIDG units to achieve a free/wide range of impedance shaping. The OVR facilitates the optimal impedance shaping based on the control requirement and grid impedance characteristics, which makes the IIDG units consistent with the power network, thus contributing to stabilizing modern power systems and autonomous NMGs.

Numerical and simulation results in MATLAB\Simulink platforms are executed to evaluate the effectiveness and accuracy of the proposed methods.

Keywords:

Droop control; Inverter interfaced distributed generation (IIDG); Microgrid; Optimal control; Fuzzy control; Robust control; Small-Signal model.