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Distributed Control, Optimization, Coordination of Smart Microgrids

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Distributed Control, Optimization, Coordination of Smart Microgrids

Passivity, Output Regulation, Time-Varying and Stochastic Loads

Amirreza Silani

university of
 groningen

The research described in this dissertation has been carried out at the Faculty of Science and Engineering, University of Groningen, the Netherlands.

The research described in this dissertation has been carried out at the Faculty of Science and Engineering, University of Tehran, Iran.

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**Passivity, Output Regulation, Time-Varying
and Stochastic Loads**

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and in accordance with
the decision by the College of Deans
and

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Friday 19 February 2021 at 11.00 hours

by

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To my family

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which means that "I wrote this poetry such that no one else knows its mysteries, please read it with your magnanimity in a way that you preserve these mysteries."

Amirreza Silani
Groningen
June, 2020

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List of symbols and acronyms

$\mathbb{C}$	set of complex numbers
$\mathbb{R}$	set of real numbers
$\mathbb{N}$	set of natural numbers
$\mathbb{R}_{\geq 0}$	set of real nonnegative numbers
$\mathbb{I}_n$	identity matrix of n dimension
$\mathbf{0}$	vector of all zeros or the null matrix of suitable dimension(s)
$\mathbf{1}_n$	n -dimensional vector of all ones
x_i	i -th element of vector x
$\dim(\mathbb{W})$	dimension of a space $\mathbb{W}$
$\det(A)$	determinant of a matrix A
$\text{tr}(A)$	trace of a matrix A
$\text{rank}(A)$	rank of a matrix A
$\text{col}(x_1, \dots, x_n)$	column vector of $x_1, \dots, x_n$
$\text{row}(x_1, \dots, x_n)$	row vector of $x_1, \dots, x_n$
$\text{diag}(x_1, \dots, x_n)$	diagonal matrix whose diagonal entries are $x_1, \dots, x_n$
$[x]$	diagonal matrix whose diagonal entries are the components of x
$\text{blockdiag}(A_1, A_2)$	block diagonal matrix whose diagonal entries are A_1, A_2
$A > 0$ ($A < 0$)	positive (negative) definiteness of a symmetric matrix A
$A \geq 0$ ($A \leq 0$)	positive (negative) semidefiniteness of a symmetric matrix A
$\mathcal{L}S(x)$	Ito derivative of a function $S(x)$
$L_g h(x)$	Lie derivative of a function $h(x)$ along a function $g(x)$
$\bar{x}$	a steady-state solution to a system $\dot{x} = \zeta(x)$
$\mathbf{x}, \mathbf{u}$	a solution to a partial differential equation
$*$	elements of a matrix whose values are not important
$\ A\ $	norm of matrix A
$\sigma(A)$	spectrum of matrix A
$\mathcal{K}(\mathcal{K}_\infty)$	class $\mathcal{K}$ ($\mathcal{K}_\infty$) functions
$\mathbb{E}(x(t))$	expected value of stochastic variable $x(t)$
$o^k(v)$	a generic function of v which is zero up to k th order

AC	alternating current
DC	direct current
DGU	distributed generation unit
EV	electric vehicle
OLFC	optimal load frequency control
EMS	energy management strategy
DER	distributed energy resource
DG	distributed generation
DS	distributed storage
PV	photovoltaic
WT	wind turbine
MGCC	microgrid centralized controller
LC	local controller
ORP	output regulation problem
PDE	partial differential equation
OPF	optimal power flow
PCPM	predictor corrector proximal multiplier
EPLL	enhanced phase locked-loop
G2V	grid-to-vehicle
V2G	vehicle-to-grid
SoC	state of charge
ESI	environmental self-identity
TSO	transmission system operator
DSO	distribution system operator
BtG	buildings-to-grid