This book presents a set of proposals for advanced control functionalities in order to achieve a coordinated and optimized voltage management of distribution networks comprising several Distributed Generation units, controllable loads, storage devices and microgrids. Large scale integration of Distributed Energy Resources, namely Distributed Generation at the Medium Voltage level and microgeneration at the Low Voltage level, poses several technical challenges for distribution network operation, especially concerning voltage control. Accordingly, the development of specific control solutions is required in order to maximize the integration of these units in the distribution system. The work presented here focused on the development of a conceptual framework model for regional ancillary services markets for voltage control. In addition, a methodology for voltage and reactive power control to be integrated in a tool for managing network operation in the short-term time-horizon is proposed.

André Madureira

André Madureira was born in Porto, Portugal, in 1980. He received an electrical engineering degree, an MSc and a PhD in Power Systems from the Faculty of Engineering of the University of Porto, Portugal in 2003, 2005 and 2010, respectively. He is currently a Senior Researcher in the Institute of System Engineering and Computers of Porto.

978-3-659-27318-6

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Impressum / Imprint
Bibliografische Information der Deutschen Nationalbibliothek: Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Coverbild / Cover image: www.ingimage.com

Verlag / Publisher:
LAP LAMBERT Academic Publishing
ist ein Imprint der / is a trademark of
AV Akademikerverlag GmbH & Co. KG
Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Deutschland / Germany
Email: info@lap-publishing.com

Herstellung: siehe letzte Seite /
Printed at: see last page
ISBN: 978-3-659-27318-6

Zugl. / Approved by: Porto, Faculty of Engineering of the University of Porto, Diss., 2010

This work was supported in part by FCT – *Fundação para a Ciência e a Tecnologia de Portugal*, under the grant SFRH/BD/29459/2006, and by INESC Porto – *Instituto de Engenharia de Sistema e Computadores do Porto*.

Acknowledgment

This work could not have succeeded if it was not for the help and contribution of several people. I hope I can do them justice and not forget anyone. Anyway, they know who they are.

First of all, I would like to thank my supervisor, Prof. João Peças Lopes. It has been my privilege to work closely with him since 2004 and it has been quite a journey since then. During these years of PhD work, he has been the beacon that kept shining when storm was raging, keeping me out of dangerous waters. His knowledge and guidance but also his dedication, commitment and especially his enthusiasm have been crucial in the making of this thesis and I could not be more grateful.

I would also like to thank Prof. Manuel Matos for his support and encouragement and particularly for his useful insights on multi-criteria decision aid in several discussions we had.

I would like to acknowledge the important contribution of my colleagues at INESC Porto that have worked with me in the MicroGrids and More MicroGrids projects, particularly Carlos Moreira but also Nuno Gil and Fernanda Resende. During all these years I have been learning a lot from our close collaboration, namely through fruitful discussions.

More thanks are due to the people who have worked with me in the Power Systems Unit of INESC Porto since 2004, especially Luís Seca, Rute Ferreira, Paula Castro, Jorge Pereira, Ricardo Ferreira, Mauro Rosa, Hrvoje Keko, Ricardo Bessa, André Moreira, Pedro Almeida, Julija Vasiljevska, Joel Soares, Leonel Carvalho, Diego Issicaba, Bernardo Silva and Ricardo Rei. All of them have contributed in several different and invaluable ways to the success of this work and I am grateful for their support and friendship.

The support of my family and friends has been so precious during these sometimes difficult times. From the bottom of my heart, thank you all.

Thank you to my parents, Carlos and Margarida, for making me who I am today. You have always believed in me even when I doubted myself. I can

never repay you enough. I know that I will never learn so much as I do from you both, every day and in every way.

Thank you to my sister Cristina who has raced with me on this PhD quest. The one time I am proud of coming second-best. I am glad I could have you next to me sharing all the distresses and happy times. Also, thank you to my nephews Afonso, Vasco e Francisco for sometimes taking me away from the dreaded claws of PhD work.

Thank you to my uncle Jorge who helped me in the final stages of printing the document.

Thank you to my closest friends, especially Tadeu, who has always been there and believed in me. You should know that I could not have done it without you.

Finally, very special thanks are due to my very special one: Sara. For all the love, support, care, patience and encouragement you have shown me, which I can barely describe in words. You truly are my inspiration. This work was done really at your expense, from the time I could not spend with you to the constant bad moods you had to endure.

Abstract

This thesis presents a set of proposals for advanced control functionalities in order to achieve a coordinated and optimized voltage management of distribution networks comprising several Distributed Generation units, controllable loads, storage devices and microgrids.

The approach followed here is based on the exploitation and extension of the microgrid concept following a massive integration of these "active cells" in electrical distribution networks. Therefore, a hierarchical control architecture is proposed in order to manage all these Distributed Energy Resources located in the distribution system in a coordinated way, based on advanced communication solutions exploiting a smart metering infrastructure. This control structure is characterized by the inclusion of an additional controller at the Medium Voltage level – the Central Autonomous Management Controller – leading to the development of the Multi-Microgrid concept.

Large scale integration of Distributed Energy Resources, namely Distributed Generation at the Medium Voltage level and microgeneration at the Low Voltage level, poses several technical challenges for distribution network operation, especially concerning voltage control. Accordingly, the development of specific control solutions is required in order to maximize the integration of these units in the distribution system.

Consequently, the work presented in this thesis focused on the development of a conceptual framework model for regional ancillary services markets for voltage control. The approach developed is able to integrate the reactive power bids from the several providers (namely Distributed Generation units or microgrids) in order to satisfy the requested reactive power needs at the Medium Voltage level, which are set by the Distribution System Operator. The market settlement is achieved based on cost minimization for the Distribution System Operator from purchasing reactive power. An ancillary services market simulator for reactive power use was developed implementing this approach for a medium-term time horizon using data from generation scheduling and renewable generation and load forecasts.

Finally, a methodology for voltage and reactive power control to be integrated in a tool for managing network operation in the short-term time-horizon has also been developed. This approach was developed in order to ensure a coordinated operation concerning the Medium Voltage and Low Voltage levels, by managing the several resources available such as Distributed Generation units, microgrids, controllable loads, On-Line Tap Changing transformers and other reactive power compensation devices. A meta-heuristic approach is used in order to optimize operating conditions. An Artificial Neural Network model has also been developed in order to replace "active" Low Voltage networks in the optimization module, making it suitable for online use in a real-time management environment.

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