IEEE - PEMC 2016 in Varna - BULGARIA
VARNA, BULGARIA | from 25 to 30 of September 2016
17th International Conference on Power Electronics and Motion Control

Tutorial: Power architectures, applications and control of DC distribution systems and microgrids

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1. Scope and benefits

DC distribution systems have higher efficiency, better current carrying capacity and faster response when compared to conventional AC systems. They also provide more natural interface with many types of RES and ESSs and better compliance with consumer electronics. Furthermore, when components are coupled around a DC bus, there are no issues with reactive power flow, power quality and frequency regulation, resulting in a notably less complex control system when compared to the AC coupled systems. All these facts lead to more and more applications of DC systems in modern power systems, including data/telecom centers, maritime industry, high voltage transmission systems, electric vehicle charging infrastructure, and DC microgrids. Still, design and operation of general DC systems imposes a number of specific challenges.

The aim of this tutorial is to identify these challenges and transmit to the audience the instructor's industrial and academic experiences in the field. Tutorial will provide a framework in hardware and control design of DC distribution systems and microgrids, as well as overview of recent research activities in this area. Practical requirements and implementation details of several types of DC distribution systems used in real world industrial applications will be presented. Also, a number of study cases power architectures will be discussed in the first part of the tutorial. On the other hand, second part will address the features of several types of coordinated control design concepts that can assure intelligent real-time control of MGs. Moreover, the concepts of constant power load (CPL) and negative impedance instability will be explained in detail. In line with this, principles of linear stability analysis techniques will be reviewed and a broad class of stabilization techniques for MGs loaded with CPLs will be presented and examined. Tutorial will also present the view of the instructor on the promising research directions and future industrial applications in this area.

2. Tutorial contents

Tutorial will be organized in the two main parts:

a) DC Distribution Power Systems Introduction: Applications, Architectures and Control

This part of tutorial aims firstly to shed light on the practical design aspects of DC distribution technology concerning typical power hardware topologies and their suitability for different existing and emerging applications. Following this introduction, a systematical control structure for DC distribution systems is presented and classified into local and coordinated control levels according to the respective functionalities in each level. As opposed to local control which relies only on local measurements, some line of communication between units needs to be made available in order to achieve coordinated control. In this view, the overall control is, depending on the communication method, divided into three basic coordinated control strategies, i.e. decentralized, centralized and distributed control. These methods are briefly reviewed and the foundation is being laid for their deeper evaluation in the second part of the tutorial.

b) DC Distribution System Coordination Strategies

The second part of the tutorial goes more in detail with regard to functionalities of each coordinated control strategy. It also assesses stability analysis and stabilization techniques for DC distribution systems. Decentralized control can be regarded as an extension of local control since it is also based exclusively on local measurements. In contrast, centralized and distributed control strategies rely on digital communication technologies. A number of approaches of using these three coordinated control strategies to achieve various control objectives are reviewed in the paper. Moreover, properties of DC MG dynamics and stability are discussed. The paper illustrates that tightly regulated point-of-load (POL) converters tend to reduce the stability margins of the system since they introduce negative impedances, which can potentially oscillate with lightly damped power supply input filters. It is also demonstrated how the stability of the whole system is defined by the relationship of the source and load impedances, referred to as the minor loop gain. Several prominent specifications for the minor loop gain are reviewed. Finally, a number of active stabilization techniques are presented.

About the instructor

Tomislav Dragičević (S'09-M'13) received the M.E.E. and the industrial Ph.D. degree from the Faculty of Electrical Engineering, Zagreb, Croatia, in 2009 and 2013, respectively. His PhD thesis has been carried out in close cooperation with industry and he has received highest honors for it. From 2013 till 2016 he has been a PostDoctoral researcher at Institute of Energy Technology, Aalborg University, Denmark, where is currently an Associate Professor. His principal field of interest is overall system design of autonomous and grid connected DC and AC microgrids, and industrial application of advanced modelling, control and protection concepts to shipboard power systems, remote telecom stations, domestic and commercial facilities and electric vehicle charging stations. He has authored and co-authored more than 80 technical papers in his domain of interest. 23 of them are published in international journals. Dr. Dragičević is a Member of the IEEE Power Electronics and IEEE Power Systems Societies. He has served in Scientific Committee Boards in several IEEE conferences and has been invited for guest lectures and tutorials in universities and companies around the world.

3. Intended audience

Researchers and engineers who seek for the basic knowledge for entering in this field, ranging from architectural design of DC distribution systems to advanced coordinated control and stabilization concepts. Prerequisite is basic knowledge about power electronics and classical control concepts.

4. Contact details

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