EPE Tutorial

TITLE

DC distribution grids: Providing comprehensive tools for a more efficient and reliable design

AUTHORS

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SCOPE AND BENEFITS

The interest on the so called DC distribution grids, DC power systems or DC micro-grids has increased in the last years, thanks to the technological evolution of the power semiconductors, the establishment of reliable power converter topologies and the apparition of cost effective protective devices among other factors. In many applications areas and scenarios, employing innovative DC grids rather than traditionally used AC grids, can produce several benefits to the system that can be measured in terms of cost, energy consumption, efficiency, volume, reliability and safety.

The main objective of this tutorial is to develop global analysis methods and global simulation tools that will enable to optimally and cost effectively design and operate efficient, safe and reliable DC distribution grid systems. The tutorial will study this issue with a general perspective, but also will apply the developed methods and analysis on one realistic specific scenario: DC distribution grids for marine vessels. It will tried to be shown that combining specialized simulation component libraries (such as *Matlab/Simulink™* & *SimPower Systems™* or any equivalent), together with oneself developed analytical models and tools, can results in an effective and holistic working approach for designers in general and specially for power electronics engineers.

CONTENTS

Monday, 11 September 2017 - Tutorial day (Location: WUT, Warsaw, Poland)

08:00 - 09:30 Registration for Tutorials

09:30 - 10:15 1. Transition towards DC distribution grids

1.1. AC vs DC distribution grids.
1.2. Topologies: -Isolated DC grids
-AC grid connected DC grids: Hybrid AC/DC grids
1.3. Control strategies: -Hierarchical control
-Distributed control
1.4. Primary control operation modes.

Summary:
The objective of this section is to present the several advantages of using Direct Current instead of Alternating Current in Medium Voltage and Low voltage Distribution grids. A classification of topologies that enable the connection of DC grid sections or microgrids over the existing AC networks are described, giving special attention to control strategies for isolated operation of these DC grids. Finally, primary control operation modes are described, showing different primary reserve sharing methods.

10:15 – 11:00 2. Primary control strategy for DC distribution grid

2.1. Introduction to low-level control strategies in AC grids
2.2. Equivalence of primary control strategies for AC and DC grids
2.3. Virtual-capacitor control for DC grids

Summary:
The main purpose of part 2 is to describe distributed primary control strategies for DC distribution grids that improve their transient behavior. The proposed techniques are inspired by the operation concept of the classical AC grid. Initially, an introduction will be carried out explaining how AC grid low-level control strategies are implemented in conventional synchronous generators. At grids where synchronous generators are substituted by power converters, the inertial response as well as primary control must be provided by these converters. Virtual synchronous machines (VSM) control techniques are an interesting alternative for this purpose, so these techniques will be introduced. Afterwards, the equivalence of AC and DC control strategies will be deduced and finally a control technique for DC grids equivalent to VSM will be proposed based on this study. One of the most relevant characteristics of the proposed technique is that different-dynamic devices—such as batteries or super capacitors—can be integrated in a simple manner by adapting control parameters.

11:00 - 11:30 Coffee break

11.30 - 12:15 3. Model and analysis of a DC distribution grid

3.1. Model and identification of the distribution system.
3.2. Model of loads, generation systems and energy storage systems.
3.3. Global analytical model of the entire DC distribution grid.
3.4. Usefulness of the global analytical model.

Summary:
In this part of the tutorial, new analytical models are presented suitable for analytically study the performance and provide design criteria of DC distribution systems. First of all, simple but accurate enough models and identification procedures of the DC distribution system are provided (cables, bus-bars, bus-ducts, shapes, geometries…). Secondly, practical analytical models of possible loads, generation and storage systems connected to the DC distribution grid are provided (embracing: power electronic converters including solutions to its non-linearities, control strategies, modulations…). Thirdly, a versatile procedure to obtain the global analytical model of the DC distribution grid is shown, comprising all the different elements connected to it and adaptable to many different possible and realistic configurations. Finally, the usefulness of the global analytical model is shown to address issues such as: Stability, frequency analysis, dynamic responses, tuning of regulators of controls, strong loads variations rejections, actively and passively power quality assessment, resonance analysis and mitigation in special converter configurations, etc…These analytical models have been already validated experimentally in test-beds close to reality.

12:15 – 13:00 4. Case study of a DC distribution system for vessels with diesel-electric propulsion

4.1. Main characteristics of the DC distribution based integrated power system including generation and loads.
4.2. Study of the performance and behavior of the global DC distribution system.
4.3. Guidelines towards design.

Summary:
In this part of the tutorial, a case study of a vessel power system based on DC distribution is studied in a more detail. The theoretical analytical models developed in previous part of the tutorial, are applied in the study of the DC distribution based vessel power system. First of all, it is shown how the physical and main characteristics of the vessel define the electric parameters and characteristics of the DC distribution. Secondly, it is shown how design parameters (choice of bust duct configurations, passive-active filters, tuning of control regulators for loads and generators, etc…) effects on issues such as: stability, damping of risky resonances, power quality, etc…Finally, in the last part, some general guidelines towards design of the DC distribution based integrated power system are provided.

13:00 - 14:00 Lunch break and registration for the afternoon tutorials

WHO SHOULD ATTEND

The tutorial attendees should be familiar with basics of power electronics, power conversion topologies, control theory applied to power converters and modelling and simulation.

We would like to encourage researchers and engineers from both industry and academia interested in fields: power electronics, DC micro-grids, power systems, marine technology, etc…

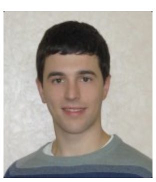
Technical Level: From beginners to advanced engineers and researchers.

ABOUT THE AUTHORS

Jon Andoni Barrena received the B.Sc. degree in electronics from the Mondragon University, Mondragon, Spain, in 2000, the M.Sc. degree (with distinction) from the University of Manchester Institute of Science and Technology, Manchester, U.K., in 2011, and the Ph.D. degree from the Mondragon University, in 2007.
Since 2008, he has been the coordinator of the Power Electronics research group of Mondragon University. His research interests include power electronics, grid quality, distributed generation, renewable energies, microgrids, energy storage systems.

Gonzalo Abad received the B.Sc. degree in electronics from the Mondragon University, in 2000, the M.Sc. degree in electrical engineering from the University of Manchester Institute of Science and Technology, Manchester, U.K., in 2001, and the Ph.D. degree in power electronics from the Mondragon University, in 2008.
Since 2001, he has been a Lecturer with the Mondragon University. His main research interests include renewable energies, power conversion, and motor drives. He has published several papers and books in these areas. He has participated in different industrial projects related to these fields and he is holder of several patents.

Juan José Valera, PhD. Industrial & Marine Business Unit, Ingeteam. B.Sc. electronics engineering, 1995 (Mondragon University), MSc 2010 and PhD (University of the Basque Country, UPV-EHU). With more than 20 years of professional experience, he is also lecturer assistant in the UPV-EHU from 2012. His main research interests include modelling and control of power converters, integrated power systems, DC distribution systems, and energy & power management systems. He has published several papers in these areas. He has participated in different industrial and research projects in these areas where he is holder of some patents.



Eneko Unamuno received the B.Sc. in industrial electronics engineering and the M.Sc. degree in power electronics and energy from Mondragon University, Mondragon, Spain, in 2012 and 2014, respectively. He is currently pursuing his PhD degree in the Electronics and Computing department, Faculty of Engineering of Mondragon University.
Since 2012, he has been working as a researcher at the Department of Electronics, Faculty of Engineering, at the Mondragon University. His research interests include microgrids, control of power converters, distributed generation and energy storage systems.

Argiñe Alacano (MSc) was born in Durango, Spain, in 1988. She received the MSc degree in Energy and Power Electronics from Mondragon University, Mondragon, Spain, in 2013 and the Ph.D. degree in power electronics from the Mondragon University, in 2017. Since 2017, she has been a lecturer with the Mondragon University. Her main research interests include renewable energies, power electronic converters, and power transmission and distribution.