Frequency Control in Low Inertia Systems: Non-Synchronous Technologies

1. Abstract

The total system inertia (*H*) is the primary source of electricity system robustness to frequency disturbances which arise due to an imbalance of generation and demand. The traditional large synchronous generators directly connected to the grid are the main sources of inertia, and they play an important role in limiting rate of change of frequency (ROCOF) and provide a natural response to the system frequency changes following an unscheduled loss of generation or demand from the power system.

The transition to a low carbon society is the driving force pushing the traditional power system to increase the volume of *non-synchronous technologies* which mainly use power converters (PCs) as an interface to the power network. The PCs decoupled the primary source from the power network, as a consequence are not able to contribute with "natural" inertia in the same way as classical synchronous generators. During a system frequency disturbance (SFD), the system frequency will change at a rate initially determined by the total system inertia (*H*). The inertial response of the system might be negatively affected with devastating consequences for system security and reliability.

The objective of this seminar is *to present the fundamental aspects about system Frequency Control in Low Inertia Systems*.

This seminar has special emphasis on non-synchronous technologies, mainly using power converters (PCs): (a) High Voltage DC (HVDC) and (b) Wind Power Integration and considers the implications on frequency control.

Keywords: Control, Frequency, Frequency support, HVDC, Inertia, Multi-terminal HVDC, Wind Power.

2. Tutorial Duration

This seminar is designed for 2-hour

4. Instructor Affiliation

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Editorial: Journal of Applied Materials and Technology
Editorial Board: Sustainability — Open Access Journal (IF = 2.592)
Advisory Editorial Board of Journal of Graphic Era University
Advisory Editorial Board of Journal of Electrical Engineering and Automation

5. Instructor Biography

Francisco M. Gonzalez-Longatt is currently a full professor in electrical power engineering at *Institutt for elektro, IT og kybernetikk,* *Universitetet i Sørøst-Norge*, Norway. His academic qualifications include first Class Electrical Engineering of *Instituto Universitario Politécnico de la Fuerza Armada Nacional*, Venezuela (1994), Master of Business Administration (*Honors*) of *Universidad Bicentenaria de Aragua*, Venezuela (1999), PhD in Electrical Power Engineering from the *Universidad Central de Venezuela* (2008) and Postgraduate Certificate in Higher Education Professional Practice from *Coventry University* (2013) and *Diploma in Leadership and Management* (ILM Level 3), Loughborough University (2018).

He is a former Lecturer in Electrical Power Systems at Wolfson School of Mechanical, Electrical and Manufacturing Engineering and member of the Centre for Renewable Energy Systems Technology (CREST) at Loughborough University, UK. He is a former academic staff of Department of Aerospace, Electrical and Electronic Engineering at the Coventry University where he started as Lecturer in Electrical Engineering in 2012 and promoted to Senior Lecturer in Electrical Engineering in 2013. He was formerly with the School of Electrical and Electronic Engineering, The University of Manchester as Postdoctoral Research Associate (2009-2011). He is a former associate professor (1995-2009) and Chair (1999-2001) of the Department of Electrical Engineering of Universidad Nacional Politécnico de la Fuerza Armada Nacional, Venezuela (1995-2009).

He is the author or editor of several books (Spanish and English) including: "Power Factory Applications for Power System Analysis", Springer; "Advanced Smart Grid Functionalities Based on PowerFactory" Springer, and "Dynamic Vulnerability Assessment and Intelligent Control for Sustainable Power Systems", Wiley.

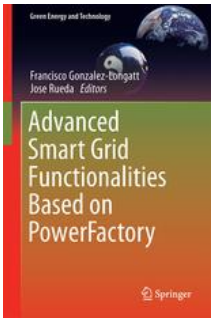
He has written 20+ book chapters,20+ journal and magazine papers and 80+ conference papers. His work has over 2.2k+ citations, and his *h*-index is 21 (June 2018), according to Google Scholar. He has been invited professor at the Master on Renewables at University of Seville, Spain, Master of Renewable at University Carlos III Madrid, Spain. He has been invited speaker at several top universities: KTH-Sweden, Leuven-Belgium, TU Delft-The Netherlands, etc.; keynote speaker several important conferences, including session chair at IEEE ISGT Asia 2019, ISGT Asia 2018, ISGT Asia 2015, IECON 2013, IEEE Powertech 2011, IEEE ISGT Europe 2011. He is a reviewer of the top conferences and journal papers research area (IEEE Transaction on Power Systems, IEEE Transaction on Smart Grids, IET Renewable Power Generation, Elsevier Renewable Energy, etc.)

He is Vice-President of *Venezuelan Wind Energy Association*, Senior Member of the Institute of Electrical and Electronic Engineering (IEEE), a member of The *Institution of Engineering and Technology* - The IET (UK) and a member of *International Council on Large Electric Systems* -CIGRE. He received the professional recognition as FHEA – Fellow of the Higher Education Academy in January 2014. His research interest includes innovative (operation/control) schemes to optimise the performance of future energy systems. His research is or has been supported by the *Royal Society*, British Council, UK India Education Research Initiative (UKIERI) –UK. He has been collaborating in European research projects, including: "Integration of Offshore wind power into the Spanish Power System using HVDC", Universidad Carlos III, Universitat Politecnica de Catalunya, Spain.

Two special research projects financially supported by the Royal Society and British Council deserve mention: "*Exploring beyond the Frontiers to Build a Smarter Grid (EBF2BSG)*" and "*Smart Multi-Terminal DC micro-grids for autonomous Zero-Net-Energy Buildings*". More recent projects include Newton-Bhabha India UK Advanced Training School (IUATS), Optimal Design and Control of Smart Community: New Ideas for off-grid Communities.

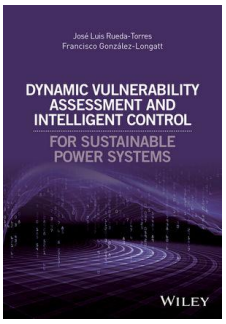
6. List of Relevant Publications in this Area by the Instructor:

[1] **F. Gonzalez-Longatt** and J.L. Rueda. "Advanced Smart Grid Functionalities based on PowerFactory". *Springer-Verlag*. 2016ISBN-13: 978-3319505312 1st ed. 2017 edition http://www.springer.com/la/book/9783319505312



Key features:
This book consolidates some of the most promising advanced smart grid functionalities and provides a comprehensive set of guidelines for their implementation/evaluation using DIgSILENT Power Factory.
It includes specific aspects of modelling, simulation and analysis, for example, wide-area monitoring, visualisation and control, dynamic capability rating, real-time load measurement and management, interfaces and co-simulation for modelling and simulation of hybrid systems. It also presents key advanced features of modelling and automation of calculations using PowerFactory, such as the use of domain-specific (DSL) and DIgSILENT Programming (DPL) languages, and utilises a variety of methodologies including theoretical explanations, practical examples and guidelines.
Providing a concise compilation of significant outcomes by experienced users and developers of this program, it is a valuable resource for postgraduate students and engineers working in power-system operation and planning.

[2] J.L. Rueda and **F. Gonzalez-Longatt**. "Dynamic Vulnerability Assessment and Intelligent Control: For Sustainable Power Systems". *Wiley-IEEE*. 2018 ISBN-13: 978-1119214953 http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1119214955.html



Key features:
Introduces behavioural recognition in wide-area monitoring and security constrained optimal power flow for intelligent control and protection and optimal grid management.
Provides in-depth understanding of risk-based reliability and security assessment, dynamic vulnerability assessment methods, supported by the underpinning mathematics.
Develops expertise in mitigation techniques using intelligent protection and control, controlled islanding, model predictive control, multi-agent and distributed control systems
Illustrates implementation in smart grid and self-healing applications with examples and real-world experience from the WAMPAC (Wide Area Monitoring Protection and Control) scheme.
Supplementary material, including MATLAB codes, available through the companion website: www.wiley.com/go/rueda_torres/dynamic

[1] F. Gonzalez-Longatt, P. Regulski, H. Novanda, V. Terzija "Impact of Shaft Stiffness on Inertial Response of Fixed Speed Wind Turbines" Automation *of Electric Power Systems*, Vol 8, No 8, April 2012. (DOI: 10.3969/j.j.issn.1000-1026.2012.08.001).

[2] F. Gonzalez-Longatt, J. Roldan, M. Burgos-Payán, V. Terzija. "Implications of the DC Voltage Control Strategy on the Dynamic Behavior of Multi-terminal HVDC following a Converter Outage". *UK and European T&D Network Solutions to the challenge of increasing level of renewable generation*. Newcastle-under-Lyme, Staffordshire UK, marc 14-15, 2012.

[3] F. Gonzalez-Longatt, "Impact of Synthetic Inertia from Wind Power on the Protection/Control Schemes of Future Power Systems: Simulation Study". *DPSP 2012 - Protecting the Smart Grid, The 11th International Conference on Developments in Power System Protection*, 23-26 April 2012, Birmingham, UK.

[4] F. González-Longatt, P. Regulski, P. Wall, V. Terzija. "Induction Generator Model Parameter Estimation using Improved Particle Swarm Optimization and On-Line Response to a Change in Frequency". I*EEE PES General Meeting 2011*, 24 – 29 July 2011, Detroit, USA. (Available online DOI: 10.1109/PES.2011.6039373)

[5] F. González-Longatt, P. Regulski, V. Terzija. "Procedure for Estimation of Equivalent Model Parameters for a Wind Farm using Post-Disturbance On-line Measurement Data". *IEEE PES: European conference and exhibition on Innovative Smart Grid Technologies* (ISGT-EUROPE 2011), 11-13 October 2011, Manchester, UK.

[6] F. González-Longatt, P. Regulski, P. Wall, V. Terzija. "Fixed Speed Wind Generator Model Parameter Estimation using Improved Particle Swarm Optimization and System Frequency Disturbances". *IET Renewable Power Generation Conference 2011*, 6 - 8 September 2011, Edinburgh, UK.

[7] F. González-Longatt, P. Wall, V. Terzija. "Impact of the shaft stiffness in the inertia response of Fixed speed wind turbines based on single cage induction generator". *Advanced Power System Automation and Protection* (APAP2011). 16-20 October 2011. Beijing, China. (ISBN: 978-1-4244-9619-8)