Luis Badesa

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Research Interests

Power system operation, Renewable energy, Electricity markets.

My research aims to facilitate a cost-effective integration of renewable energies: I develop mathematical models to operate electricity grids and markets efficiently. I focus on the low-inertia challenge present in modern power systems, which increases the risk of frequency instability and could lead to blackouts.

Education

Imperial College London, United Kingdom 2020
PhD in Electrical Engineering
Thesis: "Towards a Cost-Effective Operation of Low-Inertia Power Grids"
Supervisors: Prof. Goran Strbac and Dr. Fei Teng

University of Maine, Orono, Maine, USA 2016
MS in Electrical Engineering
Thesis: "Impact of Wind Generation on Dynamic Voltage Characteristics of Power Systems"
Ranked 1st among students in Electrical & Computer Engineering.

University of Zaragoza, Zaragoza, Spain 2014
BS in Industrial Engineering, specialisation in Mechatronics
Thesis: "FPGA-based System for Determining the Position of Pans on Induction Cooktops"

Employment

Research Associate, Imperial College London Since 2020

- Fellow of the Global Future Council on Clean Electrification, within the World Economic Forum.
- Designed the ancillary services capabilities of the bespoke Stochastic Scheduling model at Imperial College. This model has been used to inform policy by the UK Ministry of Business, Energy & Industrial Strategy (BEIS), and the Committee on Climate Change (CCC).
- Deduced, for the first time, spatio-temporal frequency stability conditions, guaranteeing stability for systems with renewables placed in remote locations (typical characteristic of most good wind resources). Made the model open-source, link here.

Energy Consultant, Arup, London, UK 2019 – 2020

- Enhanced Arup's electricity market modelling capabilities by integrating ancillary services requirements with energy dispatching.

- Advised public and private clients through numerical studies using the optimisation tool Plexos: capacity expansion for future net-zero emissions systems and forecast of electricity prices in a 30-year horizon.
- Prepared successful proposals for competitive international projects.

Researcher in Mathematical Optimisation for Power Systems, Imperial College London 2016 – 2019

- Created an open-source model that, for the first time, finds the optimal portfolio of ancillary services for guaranteeing frequency stability, and computes shadow prices for multi-speed frequency response.
- Introduced convex optimisation techniques for guaranteeing stability in electricity markets, achieving significant economic savings and reduction in carbon emissions.

Graduate Research Assistant in Smart Grid, University of Maine 2014 – 2016

- Designed a synchrophasor-based method improving the monitoring of transient stability limits, in collaboration with Central Maine Power Company (subsidiary of Iberdrola).
- Developed a tool in the Power System Analysis Toolbox (PSAT) to automatically study dynamic voltage performance after faults, drastically reducing the time for analysis.

Undergraduate Research Assistant in Digital Electronics, University of Zaragoza 2013 – 2014

- Designed and built a low-cost, FPGA-based position sensor for pans on induction cooktops, in collaboration with the engineers at BSH Home Appliances Group.
- Significant advantages of the proposed structure: easy-to-build sensor (just a piece of cable and a digital measurement and control tool), adaptable to different cooktop configurations.

Intern in Control Engineering, Titan International, Spain Summer 2013

- Used Programmable Logic Controllers from Siemens and Omron to control the conveyor belts of Titan's foundry.
- Thoroughly studied the fabrication process in the foundry, whose activity was focused on melting scrap metal to then cast metal pieces which would eventually be sold to build vehicles for construction sites.

Teaching Experience

Graduate Teaching Assistant, Imperial College London 2017 – 2019

- For three core modules in the undergraduate programme in Electrical Engineering: 'Mathematics', 'Introduction to computing with C++', and 'Numerical Analysis of Differential Equations'.
- Responsible for holding weekly sessions with students for interactive teaching; graded assignments and final projects.
- Developed coursework on Stochastic Programming for the module 'Selected Topics in Control Systems' of the MSc in Control Systems.
- Delivered a lecture and prepared a problem sheet on the topic 'Preventing blackouts in low-inertia power systems', for the 3rd-year undergraduate module 'Electrical Energy Systems' (material available here).

Instructor in Robotics, Johns Hopkins Center for Talented Youth, USA Summer 2016

- Taught the course "Introduction to Robotics" to gifted middle school students from all over the world, at the CTY summer camp in Loyola Marymount University (Los Angeles, California).
- Designed all lectures and projects, and provided a final individual evaluation to every student.

Research Project Supervisor at Upward Bound, University of Maine Summer 2015

- Supervised a high school student on a month-long project titled "Optimal Design of an Average-sized One-bedroom Apartment for Better Energy Conservation".
- Designed all steps of the project and provided personalised training on the software AutoCAD.

Mathematics tutor for high school students, Zaragoza, Spain 2012 – 2014

- Provided personalised tutoring for high-school students preparing the national university-entrance exam.

Publications

PhD thesis

Luis Badesa, "Towards a Cost-Effective Operation of Low-Inertia Power Systems," PhD thesis, Department of Electrical and Electronic Engineering, Imperial College London, 2020.

Journal articles

7. **L. Badesa**, F. Teng and G. Strbac, "Conditions for Regional Frequency Stability in Power Systems—Part II: Applications," in *IEEE Transactions on Power Systems* (under review), link to pre-print.
6. **L. Badesa**, F. Teng and G. Strbac, "Conditions for Regional Frequency Stability in Power Systems—Part I: Theory," in *IEEE Transactions on Power Systems* (under review), link to pre-print.
5. J. Guo, **L. Badesa**, F. Teng, B. Chaudhuri, S. Y. R. Hui and G. Strbac, "Value of Point-of-load Voltage Control for Enhanced Frequency Response in Future GB Power System," in *IEEE Transactions on Smart Grid*, 2020, link.
4. **L. Badesa**, F. Teng, and G. Strbac, "Pricing inertia and frequency response with diverse dynamics in a Mixed-Integer Second-Order Cone Programming formulation," in *Applied Energy*, vol. 260, p. 114334, 2020, link.
3. **L. Badesa**, F. Teng and G. Strbac, "Optimal Portfolio of Distinct Frequency Response Services in Low-Inertia Systems," in *IEEE Transactions on Power Systems*, 2020, link.
2. S. Camal, F. Teng, A. Michiorri, G. Kariniotakis and **L. Badesa**, "Scenario generation of aggregated Wind, Photovoltaics and small Hydro production for power systems applications," in *Applied Energy*, vol. 242, pp.1396-1406, 2019, link.
1. **L. Badesa**, F. Teng and G. Strbac, "Simultaneous Scheduling of Multiple Frequency Services in Stochastic Unit Commitment," in *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3858-3868, Sept. 2019, link.

Conference publications (peer-reviewed)

5. A. Mirza-Baig, **L. Badesa** and G. Strbac, "Importance of Linking Inertia and Frequency Response Procurement: The Great Britain case," in *2021 IEEE Madrid PowerTech* (under review).
4. **L. Badesa**, F. Teng and G. Strbac, "Optimal Scheduling of Frequency Services Considering a Variable Largest-Power-Infeed-Loss," in *2018 IEEE Power & Energy Society General Meeting (PESGM)*, Portland, OR, link.
3. **L. Badesa**, F. Teng and G. Strbac, "Economic value of inertia in low-carbon power systems," in *2017 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe)*, Torino, link.
2. **L. Badesa**, S. Fathima, M. T. Musavi and P. Villeneuve, "Impact of Wind Generation on Dynamic Voltage Stability and Influence of the Point of Interconnection," in *2016 IEEE Green Technologies Conference (GreenTech)*, Kansas City, MO.
1. Y. Wu, **L. Badesa**, M. T. Musavi and P. Lerley, "Monitoring power system transient stability using synchrophasor data," in *2015 IEEE Power & Energy Society General Meeting*, Denver, CO.

Funding & Awards

Competitive scholarships and research funds obtained, and funds raised for university activities:

- Iberdrola Scholarship for Energy and Environment Postgraduate Studies
  - Merit-based and interview process to evaluate potential. Awarded to four Spanish engineers each year, sponsored by the Iberdrola Foundation.
  - Obtained for two consecutive years (2014 and 2015).
  - **Total amount**: 85,000€.
- BSH research scholarship for conducting bachelor thesis.
  - Merit-based and interview process, sponsored by Bosch and Siemens Home Appliances group.
  - **Amount**: 3,000€.
- MOSEK scholarship for the DTU Center for Electric Power and Energy PhD summer school.
  - Covering the full fees, awarded to two attendees based on their CV and research project. Sponsored by the developer of large scale optimization software MOSEK.
  - **Amount**: 700€.
- IEEE Student Branch at Imperial College: raised funds to cover expenses for a full day conference, research symposium and technical visits.
  - Sources of funding: Imperial College and industrial sponsors ARM and Huawei.
  - **Amount**: £2,500.
- IEEE Power & Energy General Meeting accommodation grant
  - Grant covering hotel fees during the conference, obtained for the two occasions when I attended the conference as a student (2015 and 2018).
  - **Amount**: $1,500.
- IEEE Power & Energy Society Chapter at UMaine (USA), raised university funds to cover the expenses of several technical visits.
  - Sources of funding: University of Maine and IEEE.
  - **Amount**: $900.
- Scholarship for best graduating high-school student in Calatayud (Spain).
  - Awarded to the top performance by a high school student at the national university entry exams, covering tuition fees in the first year of undergraduate studies.
  - **Amount**: 1,500€.

Professional Service

- **Reviewer**: IEEE Transactions on Power Systems, IEEE Transactions on Smart Grid, IEEE Transactions on Sustainable Energy, Applied Energy (Elsevier).
- **Member of CIGRE Working Group C2.18** (since 2020)
  Wide Area Monitoring Protection and Control Systems – Decision Support for System Operators.
- **Secretary and co-founder at IEEE Student Branch**, Imperial College (2018 – 2019)
  - Organised a research symposium and a full-day conference (see the branch's website).
- **Chair of the Events Committee at IEEE PES Student Chapter**, UMaine (2015 – 2016)
  - Organized several technical visits to companies in the power sector, and career-advising sessions with the engineers in those companies.
- **Mentor for undergraduate students at Eta Kappa Nu**, University of Maine (2016)
  - Advised engineering students on how to become a competitive candidate for internships and jobs, and helped them select the best courses for acquiring the necessary skills for their future work.

- **Mentor for first-year and exchange students**, University of Zaragoza (2012 – 2014)
  - Mentored a group of 20 first-year engineering students on their academic concerns and helped international exchange students adapt to the Spanish university system.

Talks

9. 'Optimization and Pricing of Ancillary Services in Low-Carbon Electricity Grids', 2020 Online Summer Workshop in Environment, Energy, and Transportation (Economics), July 2020.
8. 'Life outside academia: my journey as an energy consultant', talk series of the Imperial College Control & Power research group, June 2020.
7. 'Preventing blackouts in low-inertia power systems', lecture for the undergraduate module 'Electrical Energy Systems' at Imperial College, September 2019 (material available here).
6. 'UK blackout of August 9th 2019: how should we operate a low-inertia power grid?', monthly seminar of the Electrical and Electronic Engineering department at Imperial College, August 2019.
5. 'Modern power systems: a challenging and exciting future', delivered to a group of visiting undergraduate students at Imperial College from Beihang University, August 2018.
4. 'Optimal Provision of Frequency Services in Decarbonised Grids', talk series of the Imperial College Control & Power research group, March 2018.
3. 'Optimal Scheduling of Frequency Services Considering a Variable Largest-Power-Infeed-Loss', IEEE Power & Energy Society General Meeting, Portland (Oregon, USA), August 2018.
2. 'Economic Value of Inertia in Low-Carbon Power Systems', IEEE Innovative Smart Grid Technologies Conference, Torino (Italy), September 2017.
1. 'Impact of Wind Generation on Dynamic Voltage Stability and Influence of the Point of Interconnection', IEEE Green Technologies Conference, Kansas City (Missouri, USA), April 2016.

Supervision

PhD students

- Cormac O'Malley, project title: "Design of balancing market for low carbon electricity system", since 2019.
- Aimon Mirza-Baig, project title: "Optimisation of ancillary services for frequency stability in electricity grids", since 2019.

Master's and undergraduate students

- Stacy Saruwatari, student of the MSc in Future Power Networks. Thesis: "AC Optimal Power Flow Problem using Second-Order Cone Approximations of Mesh Distribution Networks". Submission date: September 2019.
- Keerthanen Ravichandran, student of the BEng in Electronics and Information Engineering, Thesis: "Data-driven techniques to obtain constraints for optimisation problems". Submission date: June 2019.
- Mengchu Zhao, student of the MSc in Control Systems. Thesis title: "Optimal System Scheduling with Dynamic Stability Constraints". Submission date: September 2018.
- Nikolas Yiapatis, student of the MSc in Future Power Networks. Thesis title: "Frequency-Security Constraints for Multi-Area Power Systems". Submission date: September 2018.
- Sigrid Passano Hellan, student of the MEng in Electrical Engineering. Thesis title: "AC Optimal Power Flow for Networks with High Penetration of Renewable Energy". Submission date: June 2018.

Professional Membership

- Member, IEEE
- Member, CIGRE
- Tau Beta Pi Engineering Honor Society
- Eta Kappa Nu Electrical and Computer Engineering Honor Society

Software Developed

Stochastic Unit Commitment model for power systems with high share of renewables

- Computes the optimal schedule of the different generation units in a power system to meet the electric demand, while considering uncertainty in the generation of renewable sources.
- Coded in C++ to use FICO Xpress as the low-level numerical solver for the optimisation problem.
- Guarantees that the scheduling solution respects frequency stability, finding the optimal dispatch of ancillary services.
- Used to inform policy by the UK Ministry of Business, Energy & Industrial Strategy (BEIS), and the Committee on Climate Change (CCC).
- A simplified version of the model for educational purposes can be found here.

Joint market clearing of energy and ancillary services

- Convex optimisation platform for finding the optimal portfolio of energy and ancillary-services resources.
- Computes, for the first time, shadow prices for multi-speed frequency response.
- A simple version of this model along with documentation is available here.

Conditions for regional frequency stability

- Compute the necessary constraints for guaranteeing frequency stability in every region of a power grid.
- Demonstrated that this approach is key for systems with non-uniform geographical distributions of inertia (for example system with wind resources located in remote regions far from load centres).
- First approach that obtains algebraic conditions for frequency stability that go beyond the uniform-frequency model (i.e. not assuming that frequency is equal in every bus of the system).
- Available here.

Design of antenna arrays and compute their radiation patterns

- Available here, along with documentation.

Design of digital filters (IIR and FIR)

- Available here, along with documentation.

Position-estimation method for pans on induction cooktops

- Online methodology for estimating the position of a pan on top of an induction cooktop, with the estimation updated every 20ms.
- Using a VHDL model in Xilinx to measure the voltage-phase delays induced by a changing impedance of the system composed by the pan and the cooktop inductor.

Languages

- **English** (bilingual proficiency), **Spanish** (mother tongue), **French** (high proficiency, level C1).