RESEARCH GROUP

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Sustainable Energy Systems

The Sustainable Energy Systems research group seeks ways to increase the flexibility, efficiency, sustainability, reliability and social acceptance of increasingly complex and dynamic energy systems, which will be mainly powered by renewable energy sources such as solar energy, wind power or bioenergy.
It aims to bridge the gap between existing technologies and globally optimized, smart solutions for the future. In this way, the research team is focused on developing ground-breaking solutions for the challenges of future energy systems, allowing for the larger integration of renewable energy, energy storage, demand response and electric mobility including energy communities, resilient networks and efficient intelligent buildings, without forgetting system security assessment and model/data interoperability.
The research group will also work towards providing solutions to new and existing challenges in markets (local and global), including developing mathematical models to analyse market operations and proposing new market designs.

Main EXPERTISE

Specialization fields

- Renewable energy integration
- Sustainable transport and electric mobility
- Energy efficiency and energy management in buildings
- Energy markets, economics and regulation
- Digital market-based planning
- Green economy

Transversal fields

- Big Data
- Artificial Intelligence (Machine Learning models)
- Deep Learning
- Cyber-Physical Energy Systems
- Software Engineering
- Energy Cloud Computing

Research Challenges

- Shifting energy production to renewable and low-carbon sources;
- Shifting energy demand from fossil fuel to decarbonized electricity, hydrogen or heat;
- Developing flexibility systems able to respond to the inherent uncertainty of complex renewable energy systems;
- Holistically integrating electricity, gas and heat networks optimally;
- Coordinating developments of variable renewable energy sources, flexibility options, energy infrastructures and the demand for decarbonized energy;
- Managing bi-directional energy flows, as consumers play an active role in energy supply and demand;
- Increasing system flexibility to match supply and demand dynamics more locally and over multiple time frames (e.g. improving forecasting, shortening decision-making processes, extending automation, increasing coordination, etc.);
- Unlocking demand response and integrating small-scale generation and storage, from the residential and industrial sectors;
- Modernizing energy markets to achieve a fully interconnected market with a level playing field across different energy vectors and system levels (from international trade to consumers).

Application Areas

- Renewable energy systems
- Electric network monitoring and operations
- Power system protection
- Generation and demand forecasting
- Energy-efficient buildings
- Electric vehicle charging management
- Energy communities
- Energy markets
- Computational energy intelligence
- Dynamic optimization and planning

Main Assets

- FlexiGrid – Enabling flexibility in future power grids (H2020 / 2019-2023)
- ATTEST – Advanced tools towards cost-efficient decarbonisation of future reliable energy systems (H2020 / 2020-2023)
- Combi-Cast – Combined approach for the spatial highly resolved, intra-day PV forecasting for smart distribution grid operation (FNR / 2018-2021)
- gENESiS – Energy management system for smart sustainable buildings: planning, operation and optimal integration in the smart energy (FNR / 2019-2022)
- ML4SCOPF – Machine learning-based enhancements of security-constrained optimal power flow computations (FNR / 2020-2023)

Equipment

- All-sky imager (sky cam) – “EKO ASI-16” – 180° fisheye camera pointing towards the sky to estimate “cloud cover”, to identify clouds and clear parts of the sky, to estimate the cloud movements (speed and direction)
- KEPCO 4-quadrant power supply
- NI PXI systems (industrial PC) including several measurement cards
- Measurement systems and instruments

Selected publications

- Optimal energy management in smart sustainable buildings – A chance-constrained model predictive control approach. H. Nagpal, I. I. Avramidis, F. Capitanescu and P. Heiselberg. 2021. In Energy and Buildings, vol. 248
- A Comprehensive Multi-Period Optimal Power Flow Framework for Smart LV Networks. I. I. Avramidis, F. Capitanescu and G. Deconinck. 2021. In IEEE Transactions on Power Systems, vol. 36, no. 4, pp. 3029-3041
- A Stochastic Multi-period AC Optimal Power Flow for Provision of Flexibility Services in Smart Grids. M. Usman and F. Capitanescu. 2021. presented at the IEEE PowerTech Madrid, pp. 1–6
- A New Bi-Objective Approach for Optimal Sizing of Electrical and Thermal Devices in Zero Energy Buildings Considering Environmental Impacts. M. Mehrtash, F. Capitanescu, P. K. Heiselberg and T. Gibon. 2021. in IEEE Transactions on Sustainable Energy, vol. 12, no. 2, pp. 886–896
- Practical approximations and heuristic approaches for managing shiftable loads in the multi-period optimal power flow framework. I. I. Avramidis, F. Capitanescu and G. Deconinck. 2021. In *Electric Power Systems Research*, vol. 190
- An Enhanced Optimal PV and Battery Sizing Model for Zero Energy Buildings Considering Environmental Impacts. M. Mehrtash, F. Capitanescu, P. K. Heiselberg, T. Gibon and A. Bertrand. 2020. In IEEE Transactions on Industry Applications, vol. 56, no. 6, pp. 6846–6856
- Toward Controlled Islanding for Enhancing Power Grid Resilience Considering Frequency Stability Constraints. F. Teymouri, T. Amraee, H. Saberi and F. Capitanescu. 2019. In IEEE Transactions on Smart Grid, vol. 10, no. 2, pp. 1735-1746
- Short-term and regionalized photovoltaic power forecasting, enhanced by reference systems, on the example of Luxembourg. D. Koster, F. Minette, C. Braun, et al. 2019. In Renewable Energy, vol. 132, pp. 455–470
- TSO–DSO interaction: Active distribution network power chart for TSO ancillary services provision. F. Capitanescu. 2018. In Electric Power Systems Research, vol. 163, pp. 226–230
- Critical review of recent advances and further developments needed in AC optimal power flow. F. Capitanescu. 2016. In Electric Power Systems Research, vol. 136, pp. 57–68

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