PhD Position: **Hybrid modeling of coupled multi-energy power systems**

Keywords: Data based model, gas networks, digital twins, adaptive prediction, optimal operation control

Lab: L2EP, Laboratory of Electrical Engineering and Power electronics, located at Lille – France (https://l2ep.univ-lille.fr), power system group.
The research project is managed by professors Bruno FRANCOIS, Antoine DAZIN and Xavier KESTELYN

Scientific context:

Digital twins enable real-time diagnosis of the state of systems as well as fast and accurate projections of the future behavior of real assets, enabling near real-time decision making. To make a prognosis, embedded models are required to evaluate and anticipate the responses of the system. Based on physical knowledge, a mathematical model of the system can be derived. A strong constraint is that results must be calculated in real time. Model order reduction techniques are classically implemented but are altering the accuracy and limit the development of an immersive digital twin [1]. Another solution is to learn a model from the collected data using machine learning. The choice of the most suitable machine learning technique for such modeling depends on the quantity of data, its quality and the time available to build the model. Hybrid modelling approaches, at the heart of the hybrid twin concept, propose to mix both approaches: a data based model uses collected data to enrich the existing physics based model.

In the goal to balance generation with load demands, the massive integration of renewable energy sources introduces uncertainty in the generation forecasting and can only be massively jointly deployed with alternative sources that can be quickly mobilized and associated with storage systems. While many studies exist on the optimal energy management of multi-energy networks, relatively few studies consider the inherent capacity of certain types of networks to store energy (natural gas and district heating networks, for example). This lack of work on this topic can be explained by the increased complexity in the physical modeling of gas networks and by the too often used restrictive simplifications masking the storage potential of such networks.

PhD objectives:

The research goal is the implementation of a hybrid digital twin (physical and real-time data-based modeling) of a multi-energy power network allowing optimal operating and dispatching of intermittent renewable energy based sources along with using the intrinsic storage capacity of gas networks. The digital twin will focus on the real-time modeling of a residential district equipped with PV generation. The main scientific barriers concern the choice of the level of complexity of the physical modeling of the networks, particularly those of gas, and the data to be measured allowing the enrichment of the associated physical model (hybrid modelling). These obstacles will require a bibliographic work on the state of the art of smart grid architecture modeling tools, the formalization of methods allowing the sizing and design of digital twins for multi-energy systems and the determination of needs for the implementation of real-time multi-energy digital twins for multi-objective test, control, training and optimization applications.

Ideal profile:

- A MSc in Computing Science or Electrical Engineering with a focus on energy and process engineering
- Sound knowledge in energy technology, control engineering, artificial intelligence, data science
- Ability of coding in Matlab or one higher programming language (Python, Julia, ..)
- Experience in simulation tools and power system software as for examples: Simulink, Opal RT, Spherea, RTDS, SCADA, DERMS and ADMS
- Interest in applied research work in the fields of intelligent energy systems, a past experience related to research activities will be appreciated.
- The candidate must have the ability to work independently
- Good analytical, synthesis and innovation skills
- Good communication and writing skills in English.

Benefits:

- Fully funded position with competitive stipends
- Mentorship of experts in the field
- Support for international conferences and research related travels
- Access to lab facilities, computational ressources and home industrial demonstrators for tests

Starting date: As soon as possible from now or delayed to maximum 1st December 2024, duration 36 months, full time position

How to apply ?

The application must include in the first round:

- Curriculum vitae (CV).
- Cover letter
- Obtained grades obtained during your last 3 years of graduate studies and program of courses attended by students graduated from a university abroad. Official academic transcripts must be provided for each semester of each year. If you do not have a transcript (examples: internships, breaks,...), you must enclose a justification.
- Copy (pdf) of your personal works (internship reports, professional experience, academic projects, etc...)

And in the second round:

- Photocopy of diplomas. For students with foreign degrees, the translation must be certified by a consular officer.
- Letter, name and email address of two referees
- Deadline : 30th May, 2024

Send your application to the following email addresses: bruno.francois@centralelille.fr and Xavier.KESTELYN@ENSAM.EU

Past bibliography of the research group:

[1] X. Kestelyn, G. Denis, V. Champaney, N. Hascoet, C. Ghnatios and F. Chinesta, "Towards a Hybrid Twin for Infrastructure Asset Management: Investigation on Power Transformer Asset Maintenance Management," *2022 7th International Advanced Research Workshop on Transformers (ARWtr)*, Baiona, Spain, 2022, pp. 109-114, doi: 10.23919/ARWtr54586.2022.9959914.

[2] Mohamad EL IAALI, Reza RAZI, Antoine BRUYERE, Bruno FRANCOIS, Joao SOARES, Distribution Network Digital Twin: a Basic Machine Learning based Voltage Estimator, IEEE SmartGridComm 2023, Workshop on Testbed and Digital Twin for Smart Grids, October 30th, Glasgow, Scotland

[3] M. El-Iaali, R. Razi, A. Bruyere, B. Francois, and J. Soares, A Novel Cascading Artificial Neural Networks for Enhanced Distribution Network State Estimation, *22nd IEEE Mediterranean Electrotechnical Conference (MELECON),* IEEE, 2024.

[4] Hemin Golpira, Hassan Bevrani, Arturo R. Messina and Bruno FRANCOIS, A Data-Driven Under Frequency Load Shedding Scheme in Power Systems*»,* IEEE Transactions on Power Systems, March 2023, Vol. 38, Iss. 2, pp. 1138-1150, doi: 10.1109/TPWRS.2022.3172279

[5] Egnonnumi Lorraine Codjo, Bashir Bakhshideh Zad, Jean-François Toubeau, Bruno François and François Vallée, « Machine Learning-Based Classification of Electrical Low Voltage Cable Degradation », Energies, MDPI, May 2021, https://doi.org/10.3390/en14102852

[6] B. FRANCOIS, "Orthogonal Considerations in the Design of Neural Networks for Function Approximation", Mathematics and Computers in Simulation, Vol. 41, p.95-108, Elsevier, July 1996