2025-2026 Master theses proposals

Smart microgrids

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1 Deep implicit Layers for microgrid optimization

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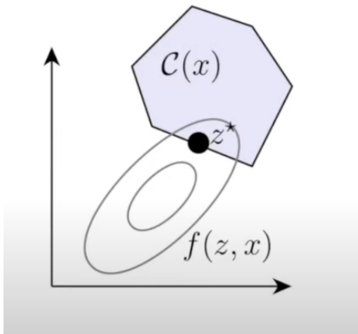
- Profile: Master in Energy, Master in Data Science, Master in Electrical Engineering, Master in Computer Science.
- Topics: Energy management, machine learning, optimization.
- Recommended courses: ELEN0445, MATH0461-2, ELEN062-1, INFO8010-1



In conventional workflows, a model is trained to predict certain parameters, which are then used in a separate optimization step to make decisions—a process known as "predict-then-optimize." However, this separation can lead to suboptimal decisions if the model's predictions are not perfectly aligned with the optimization objectives.

Decision-focused learning addresses this issue by integrating the optimization problem directly into the training process of the predictive model. This end-to-end approach ensures that the model is trained not just to make accurate predictions, but to make predictions that lead to optimal decisions when used in the downstream optimization task.

In our application, planning the operation of a microgrid, e.g. a house with PV panels, a battery, electric vehicles, and flexible loads, typically requires

1. a forecasting step to estimate the inflexible demand, the photovoltaic generation, etc., several hours in advance,
2. followed by an optimization step to decide how to control the storage systems, the flexible loads, etc.

These steps are usually performed independently.

This thesis aims to investigate the use of modern machine learning methods to merge these two steps in a single network architecture. For instance, implicit layers allow embedding optimization problems in a neural network structure.

Steps:

- Implement a benchmark with the traditional "forecast then optimize" paradigm
- Review the literature on implicit layers applied to energy management problems
- Implement a method based on implicit layers
- Compare the approaches
- If time allows, complexity the benchmark, or study opportunities to transfer the learned network to other use cases.

References:

- https://hdl.handle.net/2268/240076
- https://implicit-layers-tutorial.org/differentiable_optimization/

2 Diagnosis of the Senegalese electricity transmission network

- Contact: Amar Becegade, Bertrand Cornélusse.
- Internship organization: In the lab, opportunities to visit Senelec in Dakar.
- Profile: Master in Energy, Master in Electrical Engineering (requires at least to follow ELEC0447).

Senelec, the transmission system operator, is currently experiencing difficulties related to the operation of the electricity network. The Senegalese transmission network mainly operates with two voltage levels: 90 kV and 225 kV. However, there is an increasing installation of reactive compensation devices (VARs) on the 225 kV grid for voltage regulation. This situation is explained by the high production of reactive energy generated by these lines.

The introduction of the 225 kV voltage level began with the construction of the Manantali hydropower plant, which was integrated into the OMVS grid. Since then, this level of voltage has gradually spread throughout the country as far as Dakar, the capital, whose network was entirely 90 kV.

In the current operation of the electricity system, there are temporary disconnections of the cable between Kounoune and Patte d'Oie, which is supplied with 225 kV, especially during periods of low load. These disconnections are intended to avoid overvoltages due to the reactive power generated by this cable. In addition, other projects to install 225 kV cables are planned between the Dakar substations, which raises questions about their impact on the future operation of the network.

Generally, the choice of a voltage level is based on two key parameters: the power transit level and the distance. In Dakar, although the load density is high, the distances between stations remain relatively short.

As part of the study of the planning of the electricity network, an in-depth diagnosis of the existing network is necessary in order to identify any shortcomings and integrate them into the reflection on the future development of the network.

Thus, this diagnostic study of the electricity network aims to analyze the current situation of the Senegalese system, in particular the transits of active and reactive power. It will also assess the appropriateness of the voltage levels currently in use and examine the appropriateness of introducing an intermediate voltage level, such as 150 kV.

3 Integration of renewable energies and variability of production in Senegal

- Contact: Amar Becegade, Bertrand Cornélusse.
- Internship organization: In the lab, opportunities to visit Senelec in Dakar.
- Profile: Master in Energy.

Senegal has made significant efforts to promote renewable energies within its electricity system as part of its energy policy. Today, renewable power plants (hydroelectric, solar and wind) account for about 30% of installed generation capacity.

However, the intermittency of solar and wind sources poses challenges for managing the supply-demand balance due to their variability in production, which is often difficult to predict.

Global warming accentuates this uncertainty by impacting weather patterns, including temperature, wind speed, humidity, and precipitation. These climate impacts can greatly influence the performance of solar and wind power plants, leading to increased variability in their production over time.

In this context, it becomes necessary to integrate this variability into the calculation models to better plan the Senegalese electricity system, particularly in terms of expanding the production system.

Therefore, this study's objective is to forecast the solar and wind production profiles in each region, supporting the development of the electricity system with a view to energy transition.

4 Identification of power converter models and system-level studies

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- Organization: in the Smart Microgrids Lab.
- Profile: Master in Energy, Master in Electrical Engineering.
- Topics: Power electronics, Machine learning, Power system dynamics.
- Recommended course: ELEC0055, ELEN062-1.

Nowadays, Power systems are facing new stability challenges due to the integration of renewable energy sources and the electrification of applications. In other words, the increasing number of generators and loads connected to the grid via power electronic converters (PEC) is changing the dynamics of the power systems. The decommissioning of several synchronous generators linked to nuclear power or fossil fuels also disrupts system equilibrium. To anticipate and analyze the stability condition of the system, network operators usually refer to simulation. Unfortunatly current simulation tools are either unable to simulate the fast dynamics of PECs (RMS simulators) or unable to simulate large systems due to the complexity of PEC (EMT simulators).

In this context, this master thesis project aims to develop computationally efficient models of PECs, linked to Battery Energy Storage Systems (BESS), and to perform system-level dynamic simulation on an industrial test case (DUnEs project). The student will be accompanied by team members who have already created similar PEC models linked to photovoltaic production.

References:

- https://ieeexplore.ieee.org/abstract/document/10407755

5 Electrical vehicles integration and microgrid planning with a view on mobility demand and V2G technologies

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- Profile: Master in Energy, Master in Data Science, Master in Electrical Engineering.
- Topics: Mobility, Electrical Vehicles, Microgrids, Energy Communities, Optimization
- Recommended courses: GCIV0008-2, ELEN0445-1

As the number of electric vehicles (EVs) is currently rising, a paradigm shift in the mobility sector is occurring. Indeed, the combustion-based engines are progressively replaced by electric vehicles (EVs), which can play the role of flexible assets capable of interacting dynamically with the electrical grid.

The proposed master's thesis intends to explore the integration of EVs into microgrids, with a specific focus on assessing the possible impacts of this transition on the energy infrastructures, electrical distribution network and mobility demand. The study will investigate how EV usage could influence microgrid design and operation, particularly in the rising concept of local energy communities.

A central element of the research will be the potential of Vehicle-to-Grid (V2G) technology, where EVs not only draw power but can also supply it back to the grid, contributing to a large scale power storage, enabling load balancing, peak shaving, and further renewable energy integration. By incorporating V2G, EVs can enhance the resilience and efficiency of microgrids, especially when paired with smart charging strategies and demand forecasting.

In this context, this thesis aims to:

- Evaluate the impact of EVs integration, specifically V2G technology, on microgrid stability, flexibility, costs, and CO_2 emissions.
- Model and quantify mobility demand based on real or simulated mobility patterns.

6 Real-time distribution network control using buildings flexibility under three-phase configuration

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- Profile: Master in Energy, Master in Data Science, Master in Electrical Engineering, Master in Computer Science.
- Topics: Energy Management in Buildings, Voltage control, Optimization
- Recommended course: ELEN0445, MATH0461-2.

To address environmental challenges, prosumers have often been incentivized to accelerate their heating and mobility electrification while increasing their renewable energy production. The increased integration of low-carbon technologies, such as heat pumps, electric vehicles, battery energy storage systems, or photovoltaic panels, brings distribution networks to critical situations involving curtailment or load shedding.

Current research in our team explores how buildings, equipped with such technologies, can offer flexibility services to support voltage regulation in distribution networks and avoid such critical situations. However, existing approaches have primarily focused on balanced three-phase systems, limiting their applicability to real-world distribution grids, which are often unbalanced and more complex.

Current implementation leverages multiparametric optimization to evaluate the flexibility of assets. An exciting direction of this work is the potential application of machine learning to approximate or learn the semi-explicit policy governing asset allocation decisions.

This master thesis aims to extend these methods to unbalanced low-voltage networks and to examine the feasibility and performance of learning-based approaches to infer policy.