Imperial College London

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Department of Electrical and Electronic Engineering

Application of energy storage in systems with large penetration of intermittent renewables: Initial Report

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1 Introduction

Currently, there is a shift in how energy is generated, transmitted and distributed, which is moving the old paradigm of a centralized generation towards a more distributed one [1]. At the same time, the falling cost of solar panels [2], batteries[3] and wind turbines [4], is encouraging this kind of generation.

As most of this generation depends on intermittent natural resources which can't be manipulated, several technologies, such as energy storage or smart grids, are being developed to address the challenges presented by distributed networks, such as voltage drops, or the variability between demand and generation.

This project will aim to develop an optimization procedure to allocate energy storage in forms of batteries in a network with high penetration of renewable energy. Also, a business model will be developed for storage technologies to provide services such as congestion management, frequency regulation or energy arbitrage.

2 Methodology

For the optimization problem, an optimal power flow (OPF) framework will be approached, where a cost function will be optimized subject to network constraints. However, the OPF problem is a nonconvex problem, therefore difficult to solve. Because of this, a DC simplification of the OPF problem will be used. The software used will be Matlab© for coding and Gurobi© for solving the optimization problem.
The variables of the DC OPF are described next:

- Production of conventional units
- Charge and discharge rate of batteries
- Storage level of batteries
- Storage sizing at each node
- System voltage angles

The objective function is then defined by the energy production costs and the batteries operational and maintenance costs.

This optimization problem will be implemented first in a three-bus network as a way of testing the algorithm, and next will be done using real world information from the Uruguayan network using a simplified model of its transmission system. In the past 10 years, Uruguay has made a considerable investment in the energy sector incorporating a lot of renewable generation, particularly wind. Currently, there are weeks where the energy exported to Argentina and Brasil accounts as much as the Uruguayan demand. From an investor perspective, it is of interest to study the impact of energy storage in the wholesale market. Given the excess of renewable generation, there is a lot of time when the spot market is valued at $0\$/MWh$, and because of the sources intermittency, this market experiences spikes in prices. Therefore, this imbalances in the spot market can be exploited to maximize the revenue of an energy storage facility. On the other hand, from the government perspective, the price that the energy is exported to its neighbours its not always optimal. Then, it will be of interest to study if the incorporation of storage facilities will make it possible to take advantage of the flexibility they provide.

Considering the main objective of the coursework is fulfilled, more steps will be included in the project. First, the incorporation of electric vehicles into the modelling of the problem. Second, we will study the problem from an investment perspective when considering the Uruguayan network. There's a lot of promising opportunities for the Uruguayan energy sector to invest in energy storage technologies. This project will try to develop a simplified model of energy storage expansion planning.

3 Contents

We will divide the contents of the project into three main different topics:

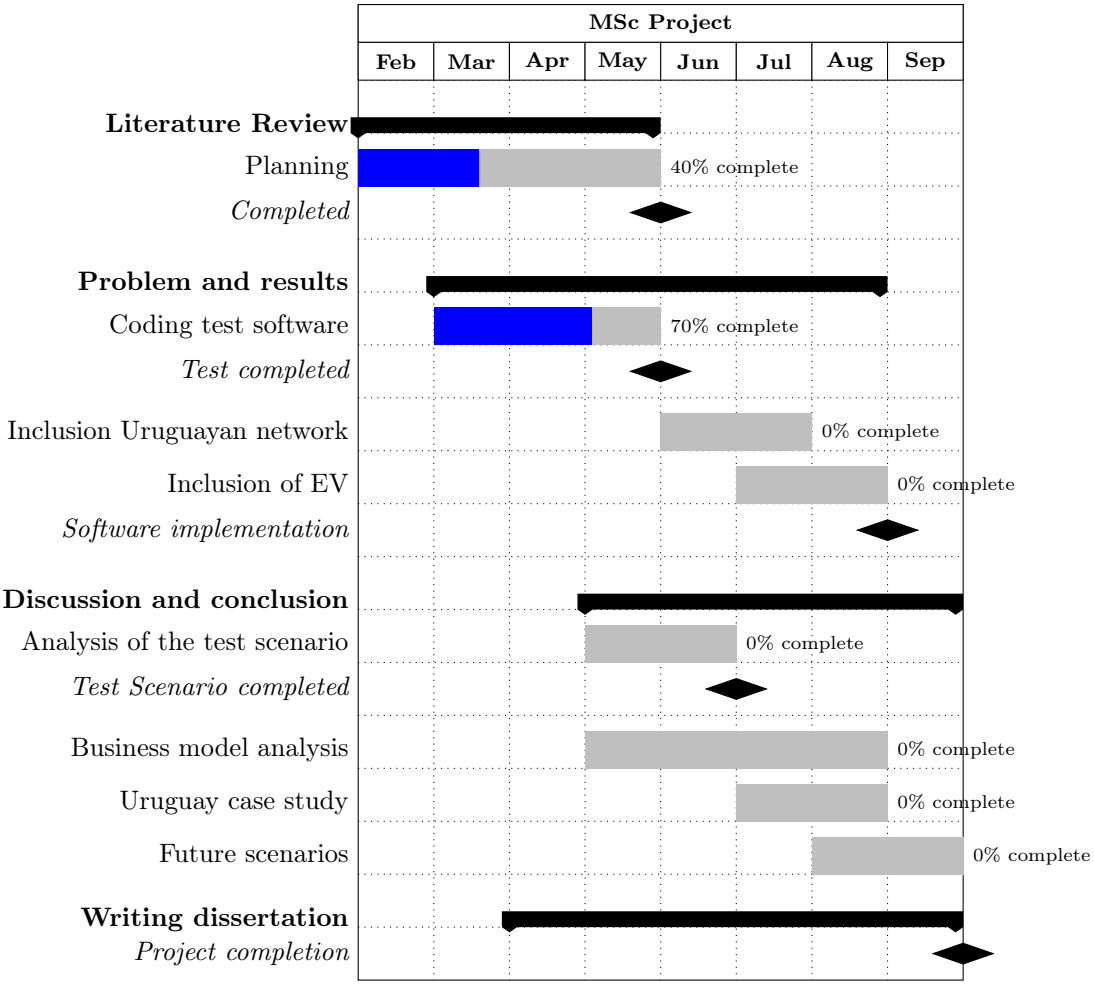
1. Literature review: The state of the art will be studied with a discussion on how power networks are shifting towards renewable and distributed generation. Also, past studies of energy storage allocations will be presented and analyzed. Finally, a thorough explanation of the Uruguayan current energy sector will be presented, explaining the achievements completed in the past years when transitioning towards renewable energy.

2. Methodology and results: In deep explanation of the methodology used for the proposed optimization problem and presenting the results obtained.

3. Discussion and conclusion: Detailed discussion on the results obtained, and implications. Study possible business models for increasing the revenue of energy storage technologies. Concluding remarks of the project and proposed future research studies.

4 Milestones

Finally an estimate of the milestones to achieve are presented next:



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