

Machine Learning–Enabled Techno-Economic Analysis of Flexible Nuclear Power for Enhanced Renewable Integration in the GB Power System

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Project Summary: This project investigates how flexible operation of nuclear power plants can support higher renewable energy integration in the GB electricity system. Using historical electricity demand, renewable generation, electricity price, and weather data, machine learning methods will be applied to identify patterns that influence grid balance and system flexibility. The project will simulate different scenarios with varying nuclear flexibility levels and nuclear capacity penetration in the generation mix. A techno-economic analysis will then evaluate potential system cost savings and operational benefits. The outcomes will identify conditions under which flexible nuclear operation—similar to practices in France—can economically improve grid stability and renewable utilisation in GB. HPC resources will enable efficient processing of large time-series datasets and rapid evaluation of multiple simulation scenarios.

Project Objectives:

- Apply machine learning to analyse GB electricity system data (demand, renewable generation, weather, and prices) to identify drivers of grid flexibility needs in GB.
- Evaluate flexible nuclear operation scenarios by modelling different nuclear flexibility levels and nuclear capacity shares in the generation mix.
- Quantify techno-economic impacts by estimating system cost savings and identifying conditions where flexible nuclear power improves renewable integration.
- Effectively leverage HPC resources to enable large-scale data analysis and scenario evaluation.

8-Week Project Schedule

Week 1 – Background Research and Project Setup

- Literature review on nuclear flexibility, renewable integration, and GB power system operations.
- Review examples such as flexible nuclear operation in France.
- Identify datasets required (electricity demand, generation mix, prices, weather).
- Set up Python environment and relevant ML/data analysis libraries.

Week 2 – Data Collection and Cleaning

- Gather historical electricity demand, renewable generation, and price data.
- Collect relevant weather datasets affecting renewable generation.

Week 3 – Exploratory Data Analysis (EDA)

- Analyse patterns in demand, renewable output, and price variability.
- Explore correlations between weather variables and renewable generation.

Week 4 – Machine Learning Model Development

- Develop ML models to analyse and predict system conditions.
- Identify features that influence flexibility needs.
- Evaluate model performance and refine features.

Week 5 – Nuclear Flexibility Scenario Design

- Define operational flexibility levels for nuclear plants (e.g., ramp rates, minimum stable output).
- Develop scenarios with varying nuclear penetration levels in the generation mix.
- Establish baseline system operation assumptions.

Week 6 – System Operation and Economic Simulation

- Simulate daily system operation under different flexibility scenarios.
- Evaluate impacts on renewable curtailment, balancing requirements, and electricity prices.

Week 7 – Techno-Economic Analysis

- Calculate economic impacts such as system cost savings and reduced curtailment.
- Compare results across flexibility levels and nuclear penetration scenarios.
- Identify thresholds where flexible nuclear becomes economically beneficial.

Week 8 – Results Interpretation and Reporting

- Identify key conditions for adopting flexible nuclear operation in GB.
- Summarise findings and implications for future energy systems.
- Prepare final report and presentation of results.

Importance of HPC Resources

HPC resources are crucial for this project because it requires analysing large historical energy and weather datasets, training machine learning models, and running multiple system simulation scenarios. These tasks involve high-resolution time-series data and extensive scenario comparisons across different nuclear flexibility levels and capacity shares. HPC enables faster data processing, more advanced machine learning modelling, and efficient evaluation of many techno-economic scenarios, making it possible to complete robust analyses within the limited timeframe of the internship.