Study Committee C1

Power System Development and Economics

Paper 10197_2022

A probabilistic approach to stability analysis for boundary transfer capability assessment

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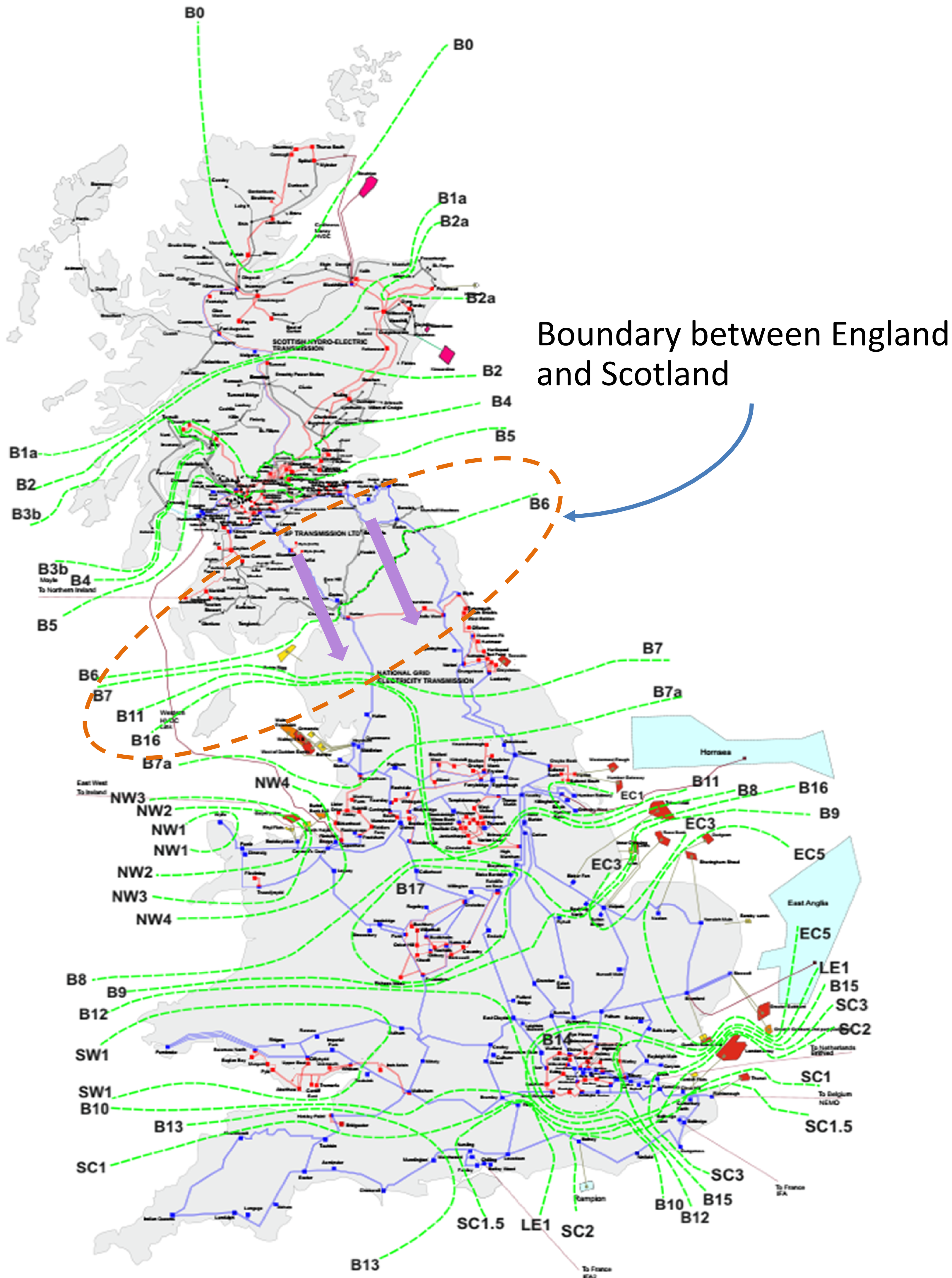
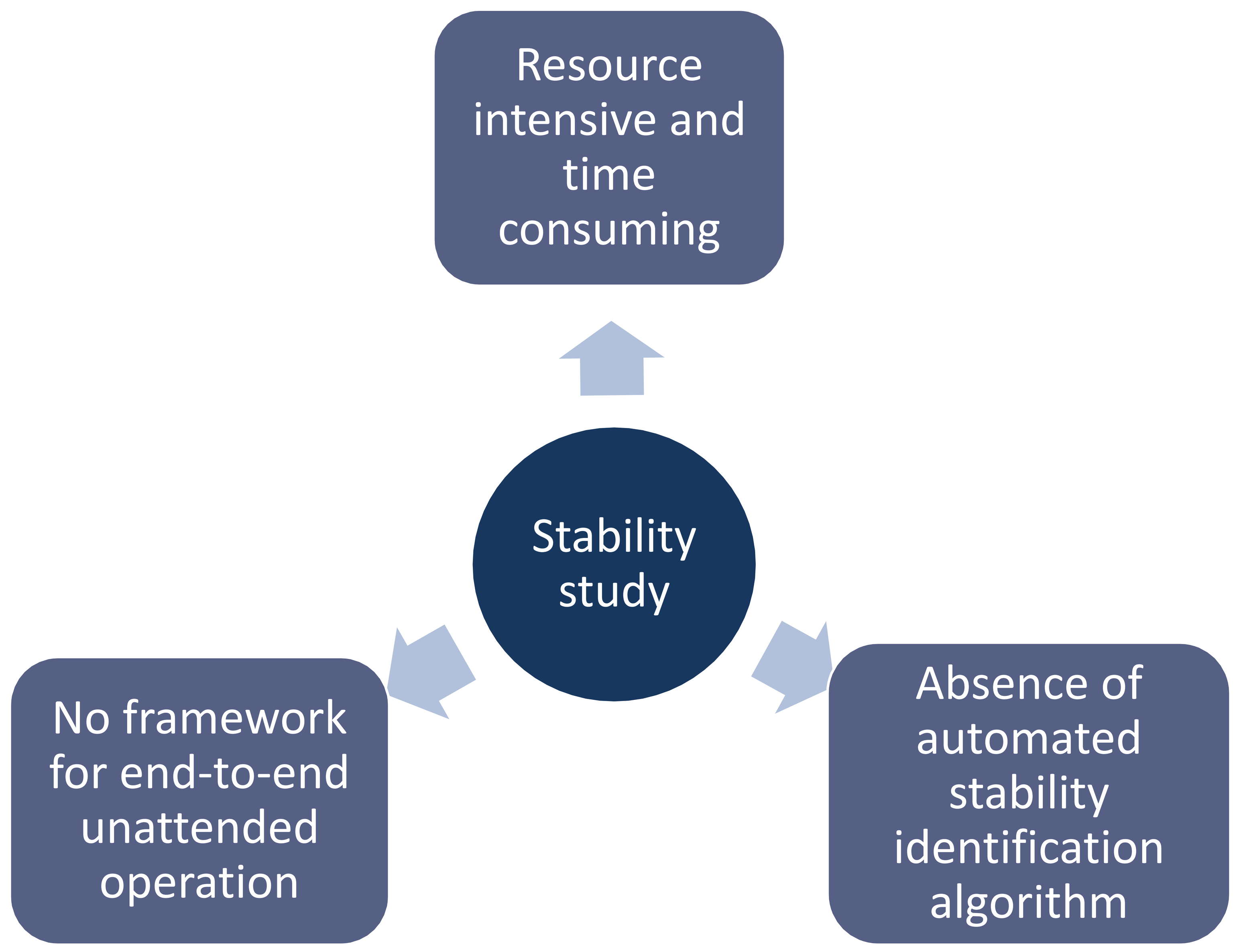
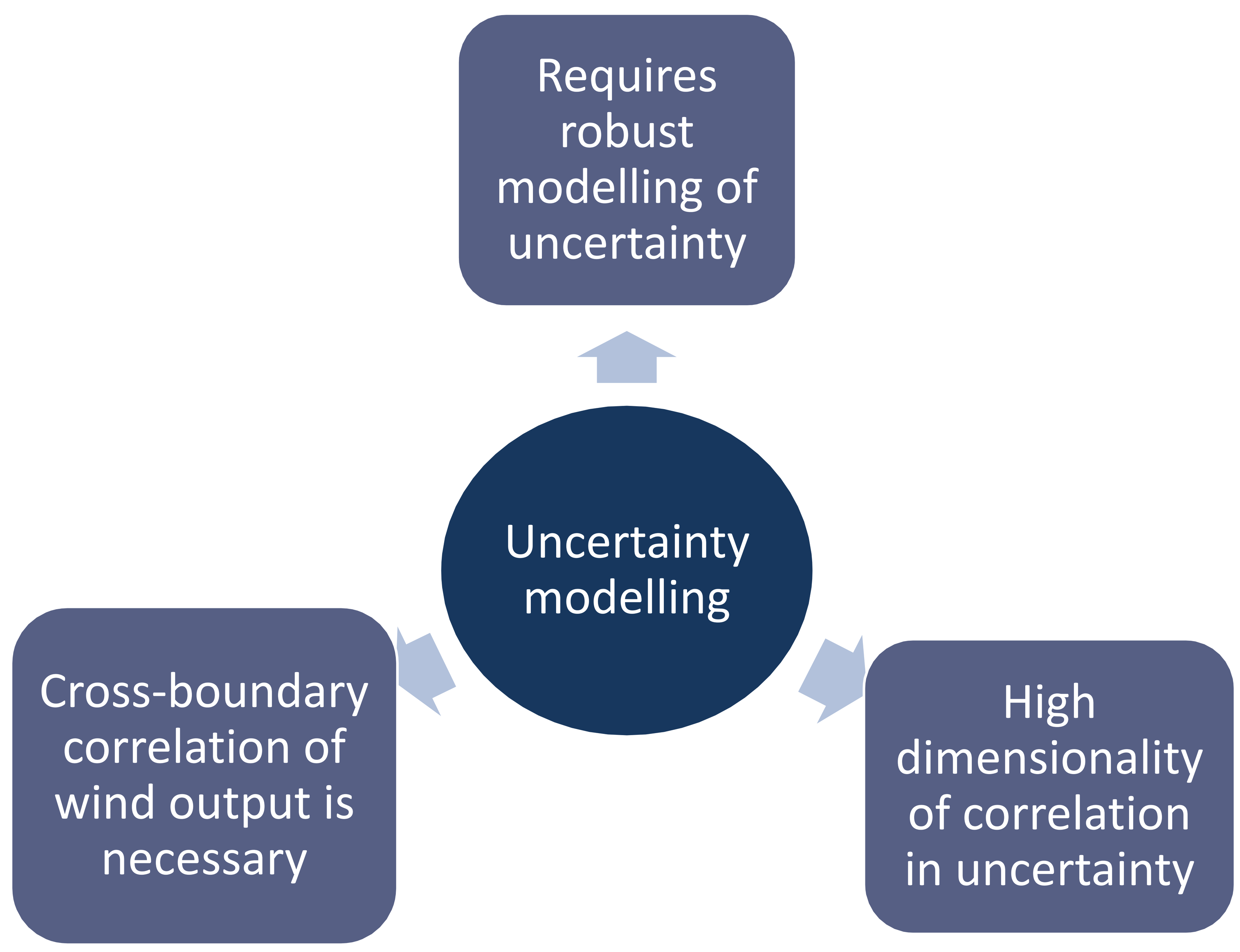
Motivation

- Increasing uncertainty in short term operational parameters (e.g., wind speed variability, demand variability)
- Uncertainty in more fundamental long-term changes (e.g., energy mix, availability of interconnectors)
- The dynamics of the system are more complex and unpredictable in certain parts of the network
- Long-term boundary capability assessment would need to be able to capture these uncertainties
- Current approach is deterministic and focuses on a selected few boundaries only and a single scenario is studied for each boundary
- A probabilistic approach is more suited to account for uncertain factors
- But high computational time in a Monte-Carlo simulation; limits the number of boundaries and scenarios that can be studied every year
- Studying each boundary currently takes a significant time as it requires manual intervention; no opportunity to run the studies unattended on several machines in parallel
- Uncertainty of the wind output and the correlation between demand at grid supply points and wind output across different boundaries is difficult to model due to the high dimension of the problem



Great Britain transmission system boundaries





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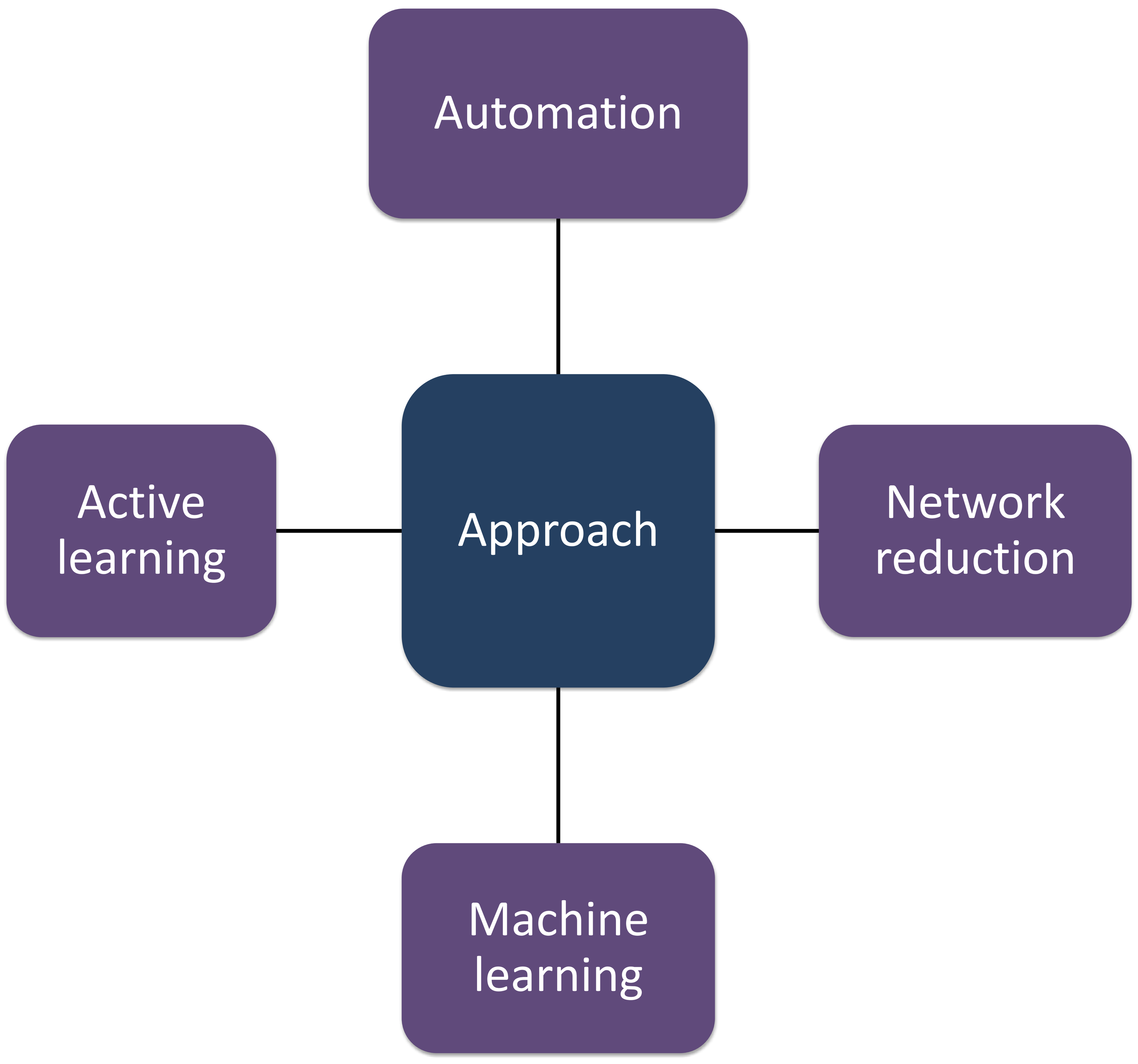
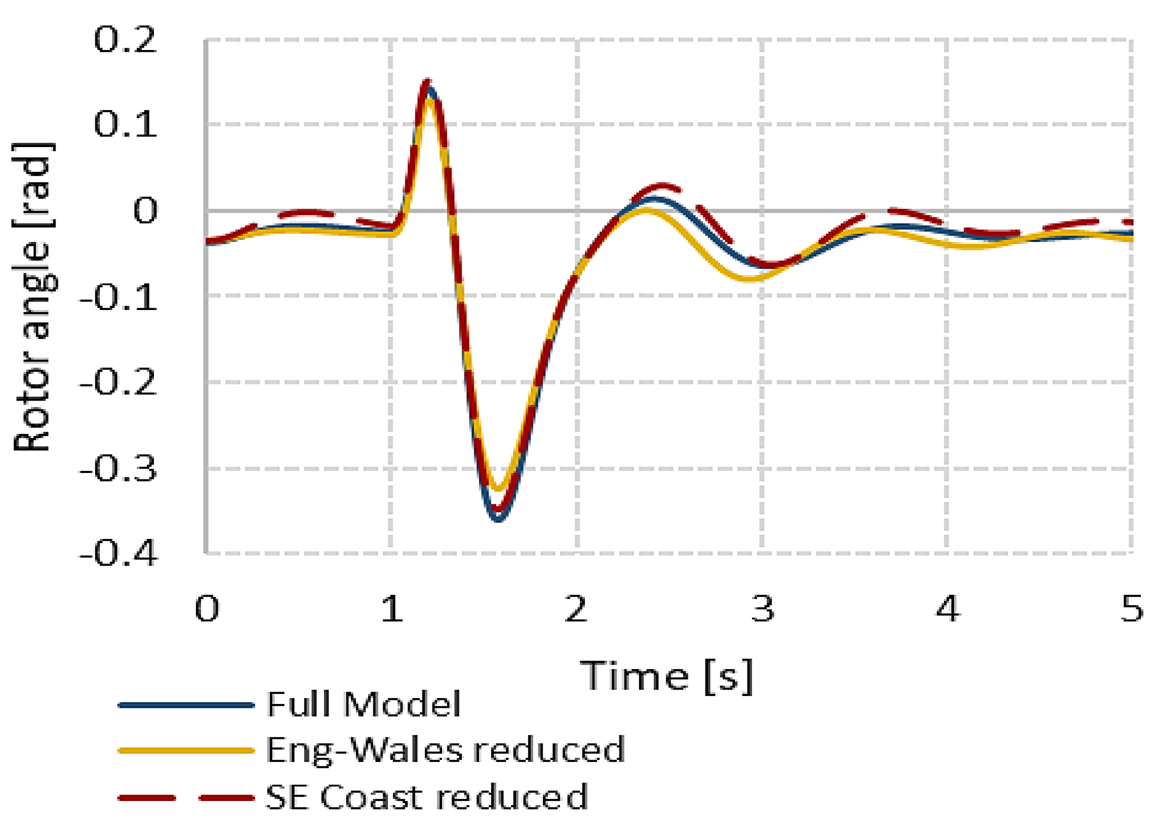
Method and Approach



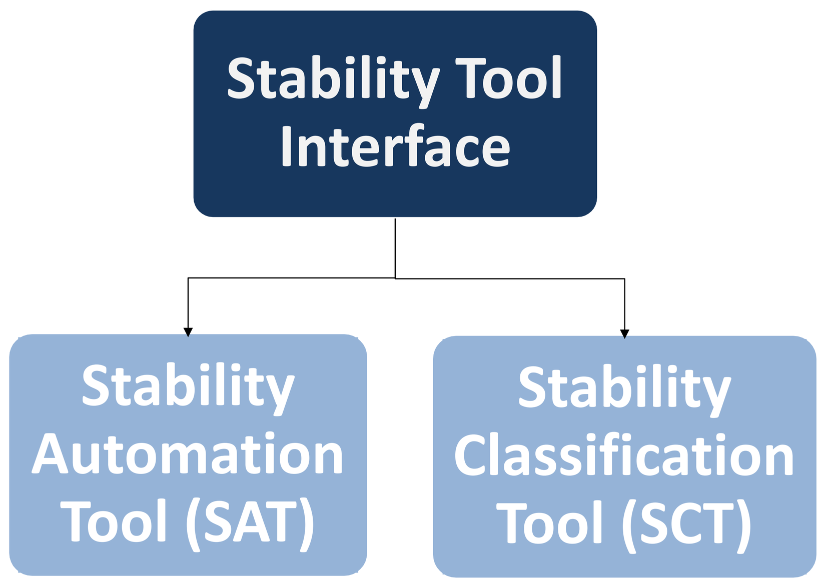
Objects of investigation

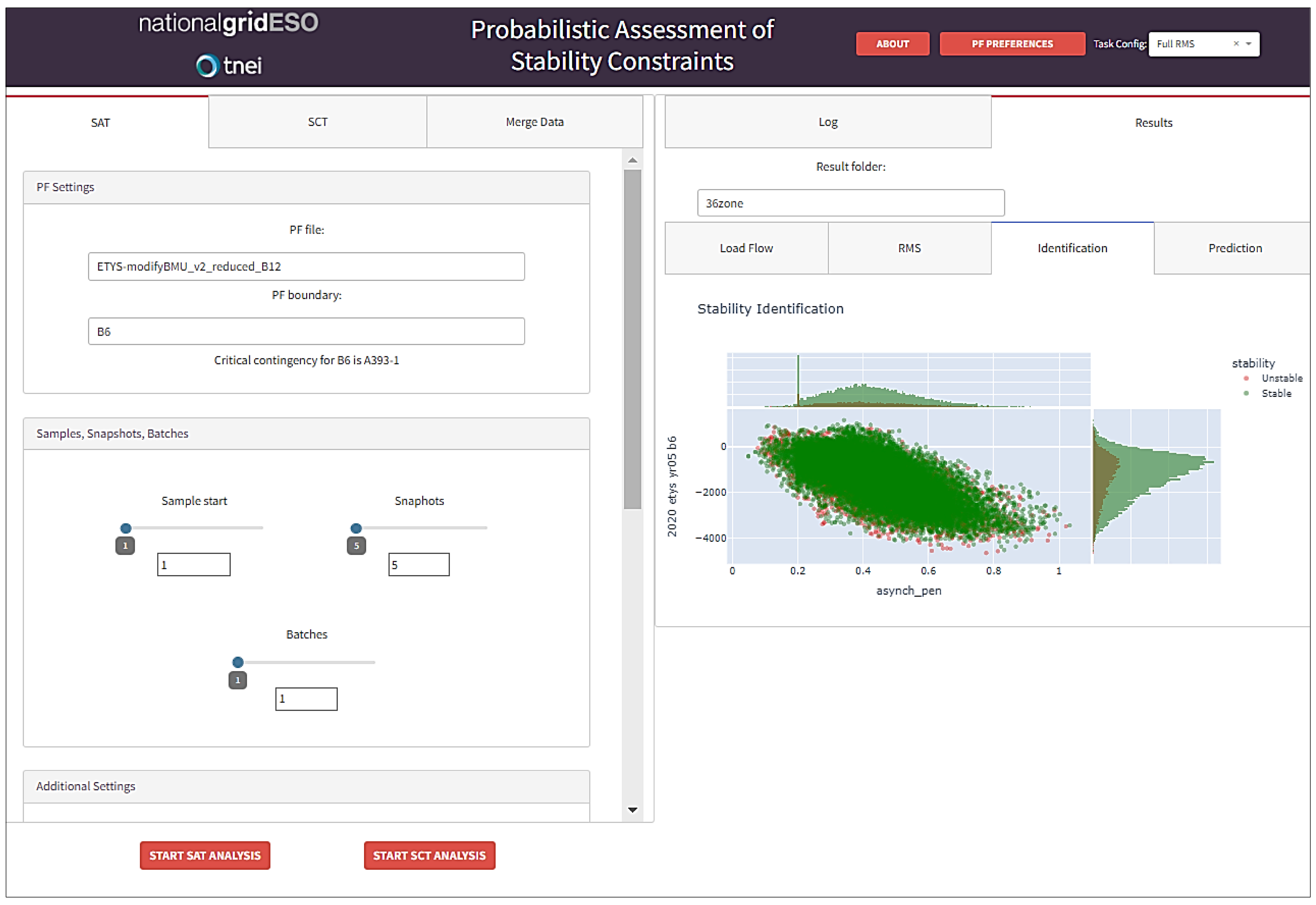
- Create an end-to-end stability analysis platform with a user interface
- Develop an algorithm to automatically resolve non-convergence issues with year-round scenarios
- Assess the suitability of using network reduction for dynamic equivalent in stability analysis
- Identify ways of dispatching generators and demand in a reduced equivalent network
- Develop an algorithm to automatically identify stability of the system
- Explore different feature engineering techniques and binary classification methods
- Develop a machine learning framework with appropriate data management system

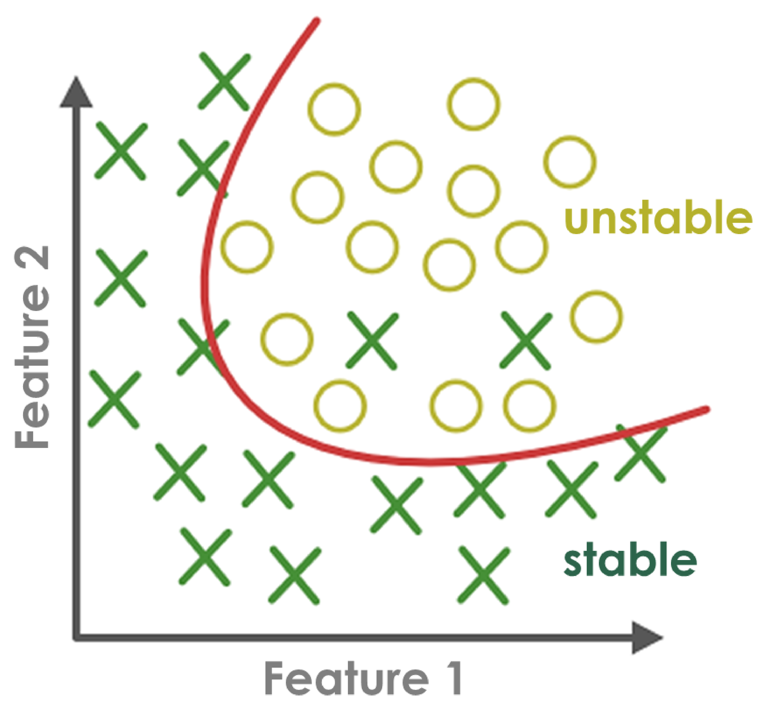


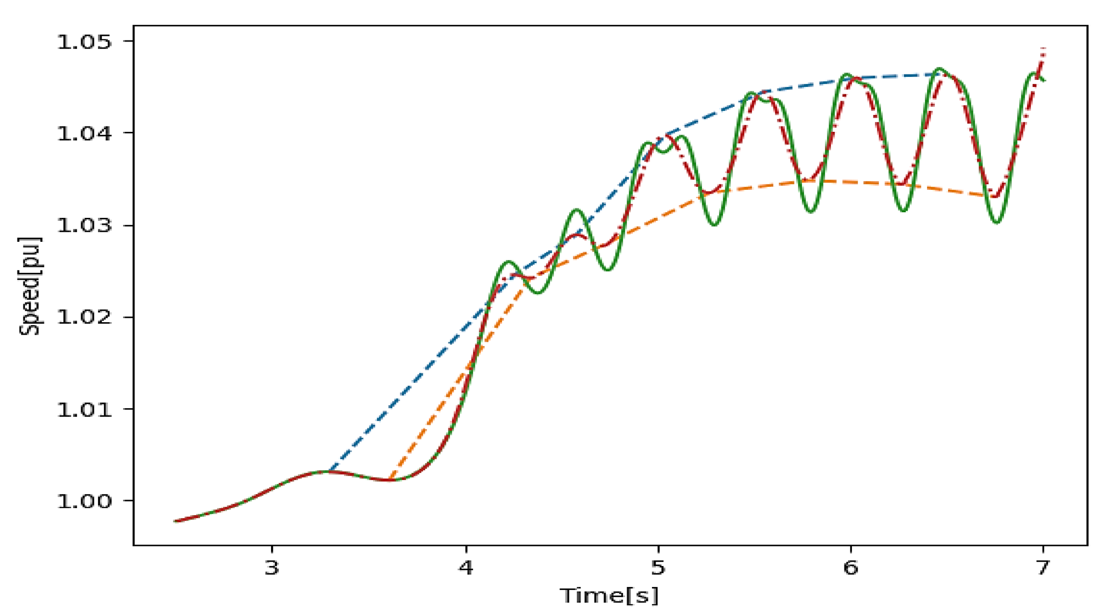
Experimental setup

- **Stability Tool Interface:** A web browser-based user interface with a visualisation platform
- **Stability Automation Tool:** A python-based tool to interface with powerfactory API and to automate several analysis steps
- **Stability Classification Tool:** A machine learning model which allows for scanning of large number of scenarios without the need for any time domain simulations









Capability of the tool - year round analysis

- DC Load flow
- AC Load flow
- Rotor angle stability
- Voltage stability (minor changes required)

Potentially extensions to the tool

- Frequency stability and impact of inertia
- Impact of short circuit on IBR performance
- Converter driven instability – slow interaction
- Dynamic voltage support

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Discussion

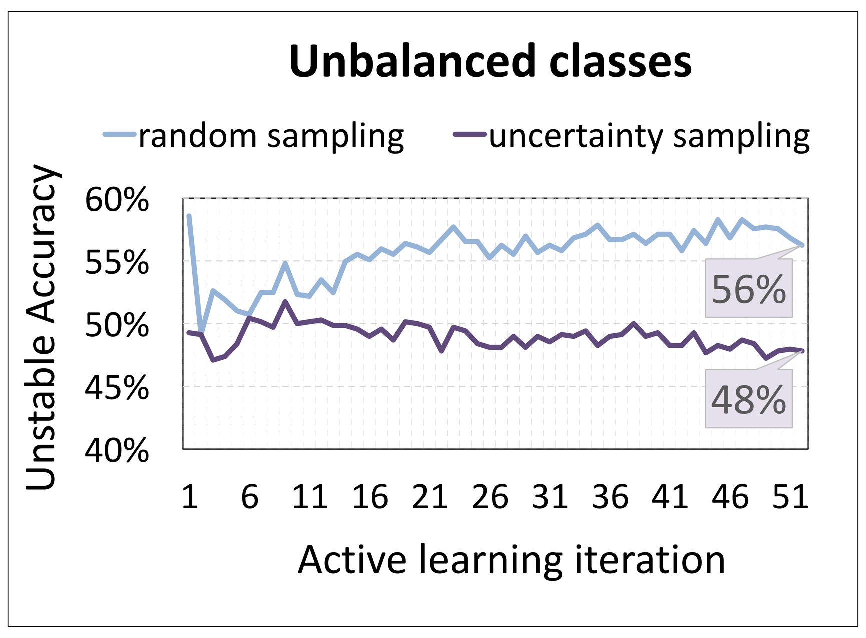
- The results presented in the paper are for the 36-zone reduced GB model
- Since then, we have improved the framework to incorporate the ETYS model (official model developed by TOs and the ESO)
- The results from the ETYS model have higher accuracy due to the granular representation of network characteristics
- Several classifier types have been compared (SVC, RFC, GPC) along with different query strategies (uncertainty, entropy), feature selection and filtering methods

Classification model

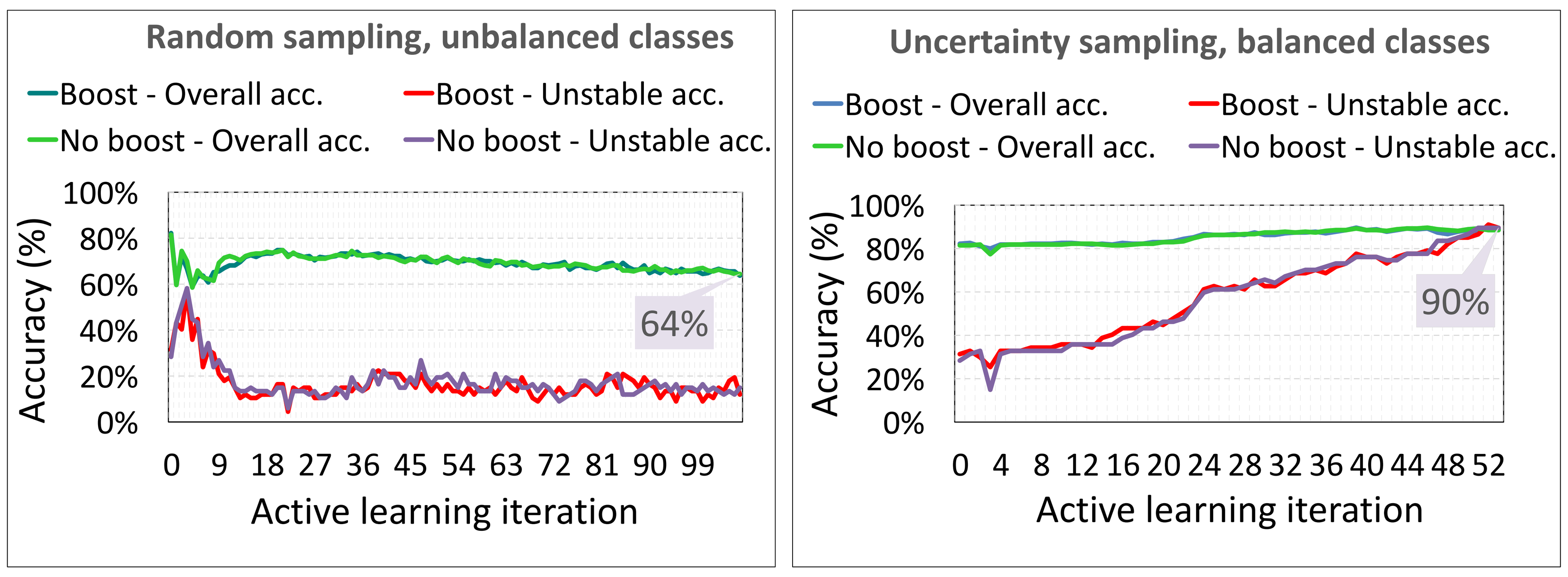
- The implementation of the classification model involves several important steps such as data cleaning, feature engineering, hyperparameter tuning etc.
- The performance of the model depends heavily on the quality of the training dataset and therefore a lot of effort is required here

Classification model accuracy

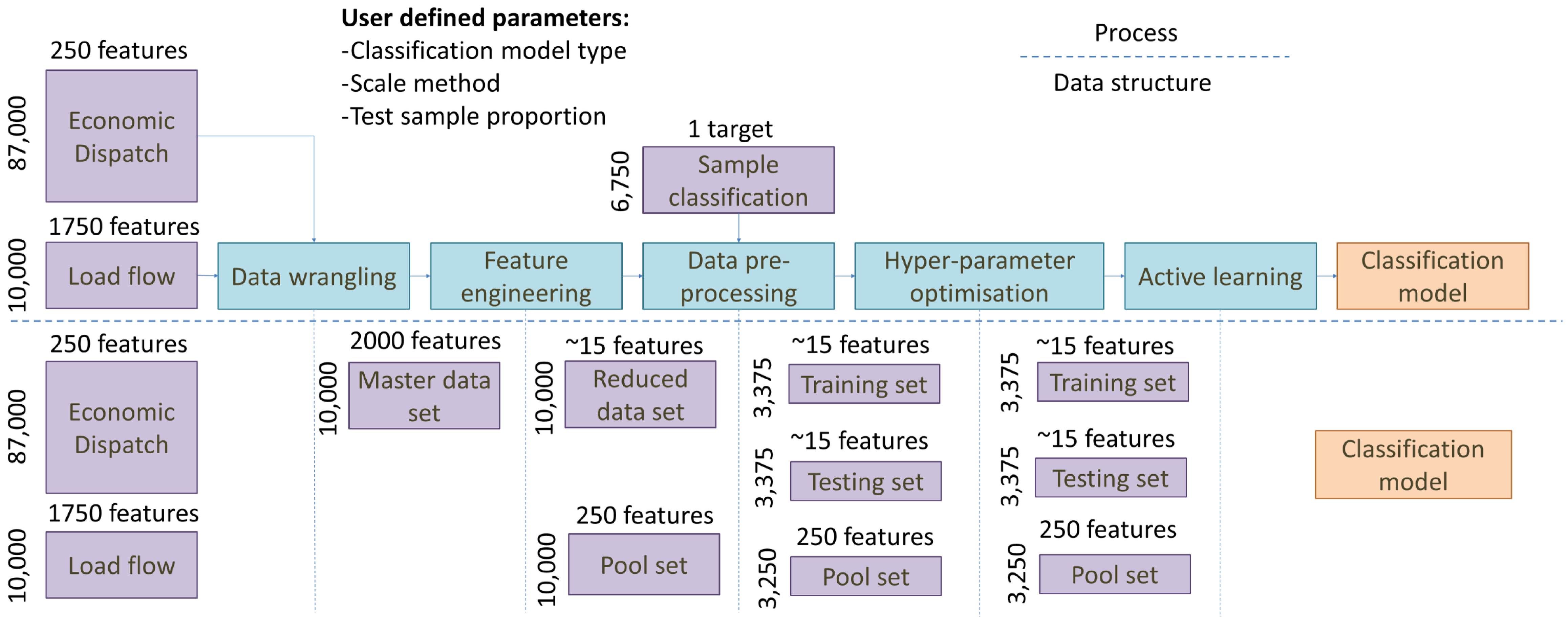
- Most often real systems will have imbalance of classes
- Class imbalance can lead to bias in the prediction of the model
- Results from 36-zone model and ETYS model show poor accuracy for the unstable class and boosting, sampling techniques do not help

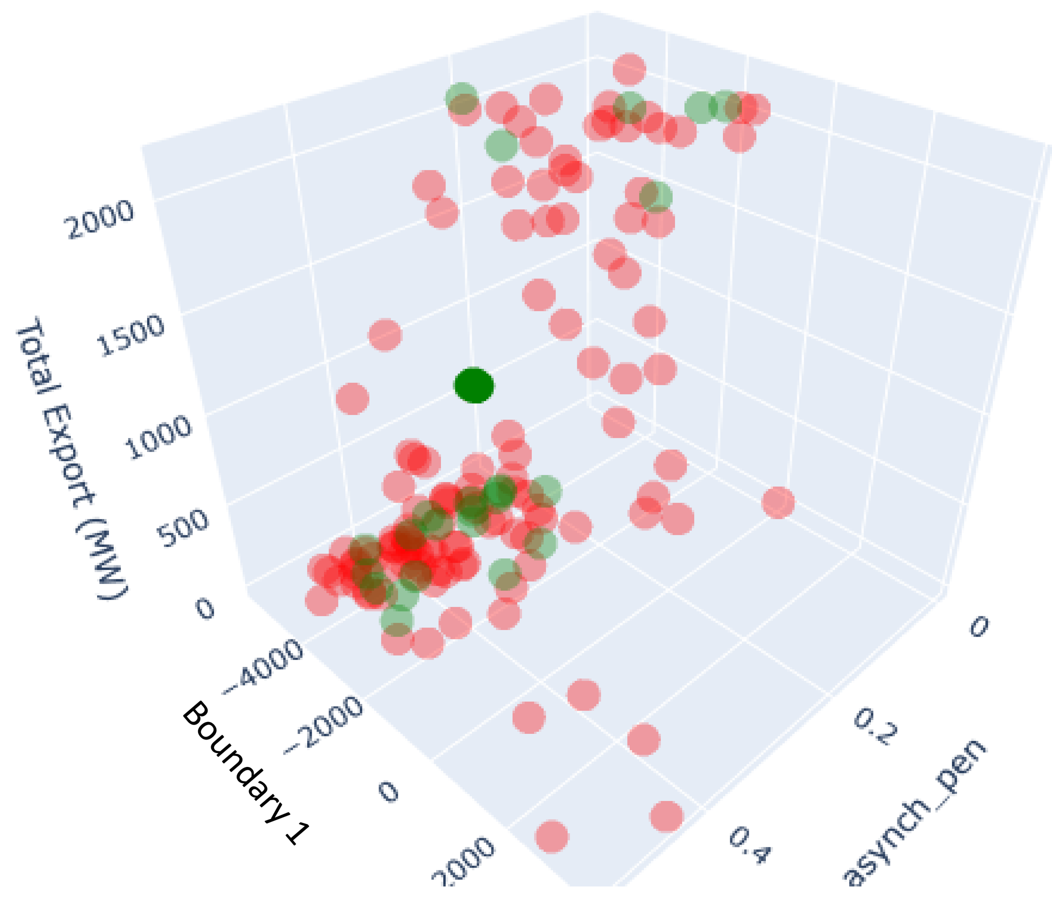


Results from 36-zone GB model



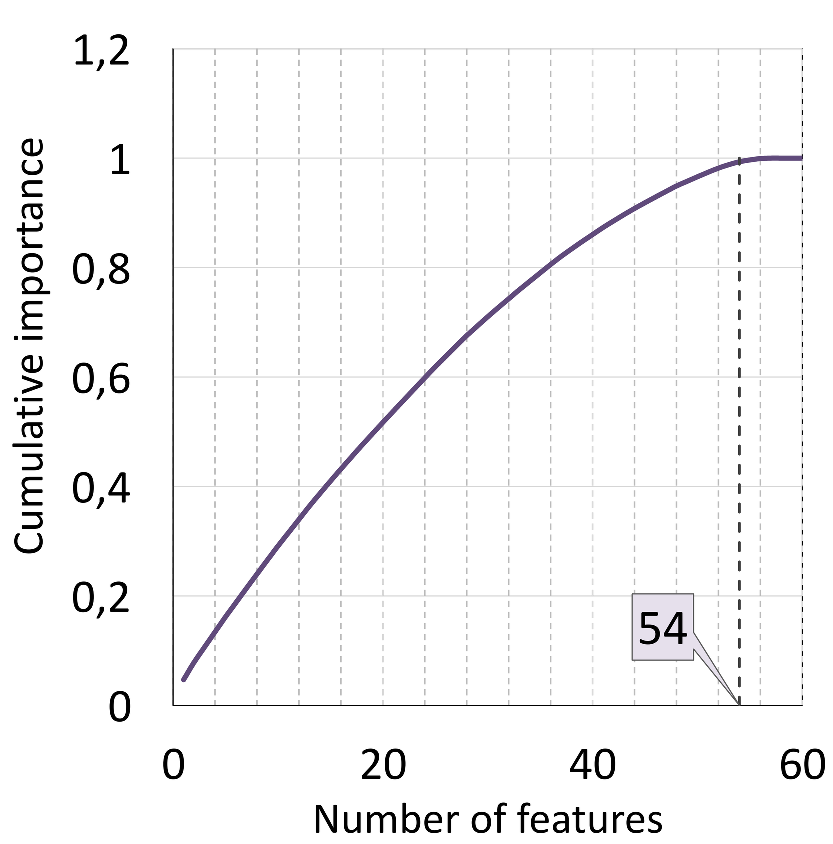
Machine learning training results for the ETYS model

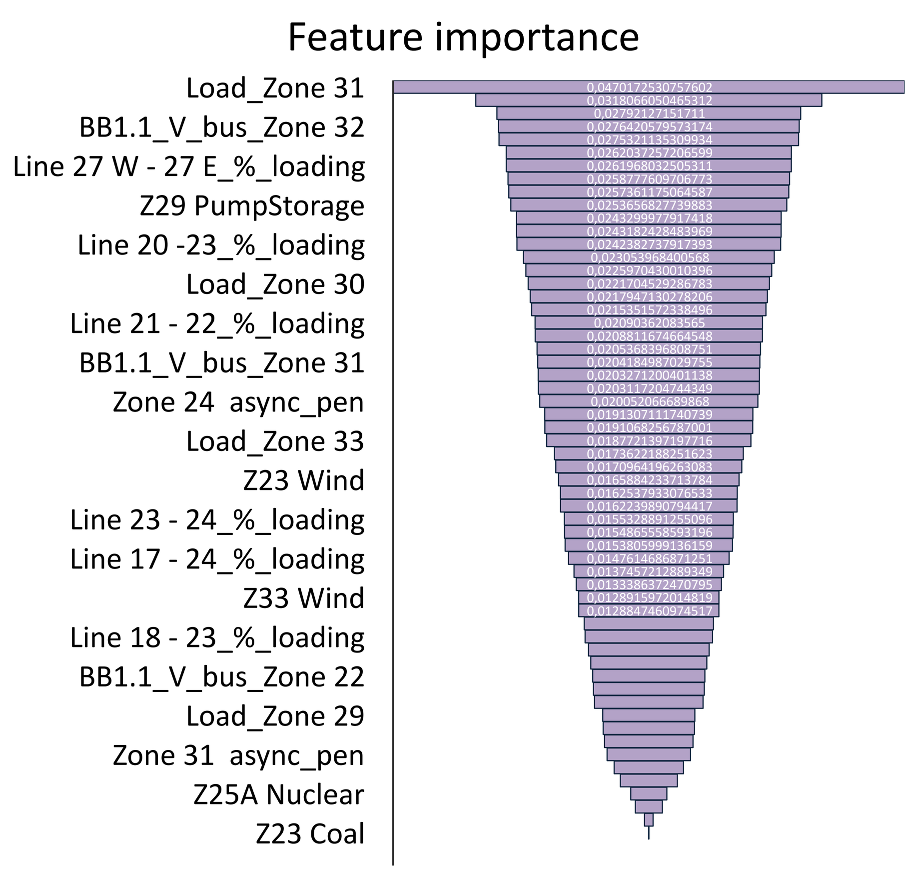




Feature selection process

- More than 2000 features in the master dataset
- Only most important features should be considered to avoid over-fitting and improve on the training time





Conclusion

- A probabilistic analysis for stability constraints is realisable through a combination of different techniques such as automation of studies, network reduction and use of machine learning models
- The stability problem can be solved as a binary classification problem and Random Forest is found to be the most effective classifier out of three with accuracy higher than 90%
- Active learning is a powerful concept, and it is useful to tackle high dimensional problems such as stability analysis of national transmission networks
- The developed tool can be used as a horizon screening method to quickly scan through a large volume of scenarios

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