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Study Committee C1

Power System Development and Economics

Paper ID - 11103

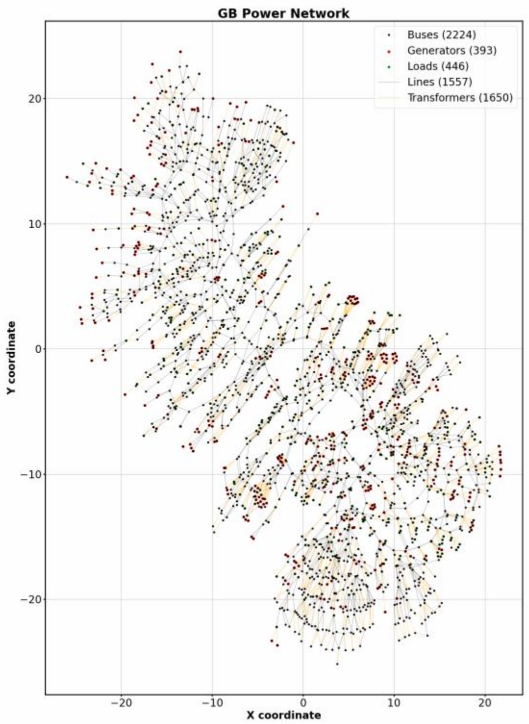
Machine Learning Method to Improve Stability Requirements Calculation for the Planning Process

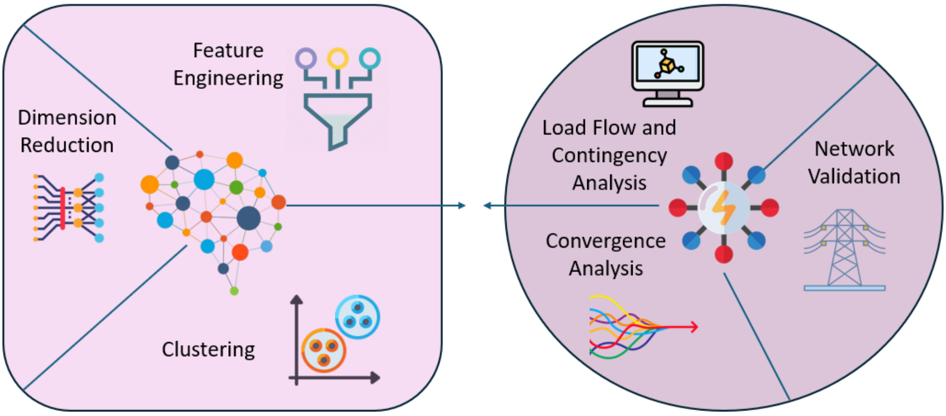
Yueqi WU, Diptargha CHAKRAVORTY, Nicolas MELCHOR

TNEI Services

Motivation

- Traditionally long-term planning of transmission networks was undertaken for a few cardinal operating points.
- Renewable energy sources introduce **uncertainty in the network planning process** leading to technical challenges such as grid stability and security.
- Therefore, system operators are looking to **adopt a scenario-based probabilistic analysis** to cover a large volume of future operating conditions.
- One of the primary challenges of scenario-based analysis is the **convergence of network load flow solutions.**
- The generation and demand dispatch information for future years usually comes from **a market simulator**.
- Market simulators implement a linearised model of the network to solve an optimisation problem and **no reactive power dispatch is considered** in the process.
- This leads to **severe load flow convergence challenges** that are difficult to resolve through trial-and-error means.
- To resolve this critical problem, there is a need to develop a clever algorithm that can utilise the **underlying information in the dispatch data** to speed-up the convergence process.
- In addition, the algorithm would need to incorporate the relationship between network topology and the location of the generation sources.
- This paper has developed an algorithm to address the above issue by combining **traditional techniques with machine learning models.**





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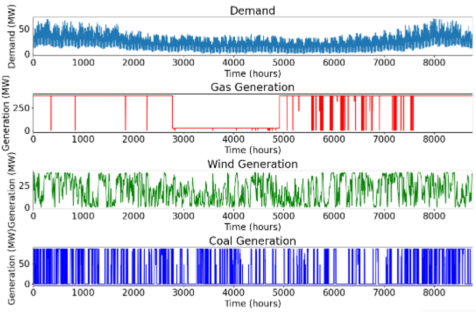
Objects of investigation

- Create an end-to-end analysis platform that automates the entire process.
- Identify variables and network characteristics that can be used as features to represent the network.
- Develop dimension reduction algorithms, specifically **Principal Component Analysis (PCA)** and **Singular Value Decomposition (SVD),** to reduce the size of the problem.
- Develop a **K-means clustering algorithm** to cluster the raw time-series data into different numbers of clusters.
- Optimise the load flow setting to improve convergence performance.

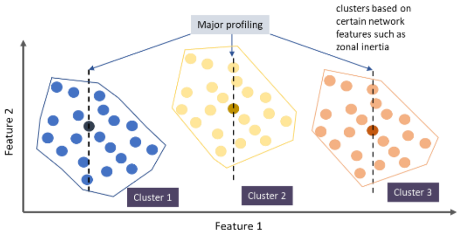
Experimental setup & test results

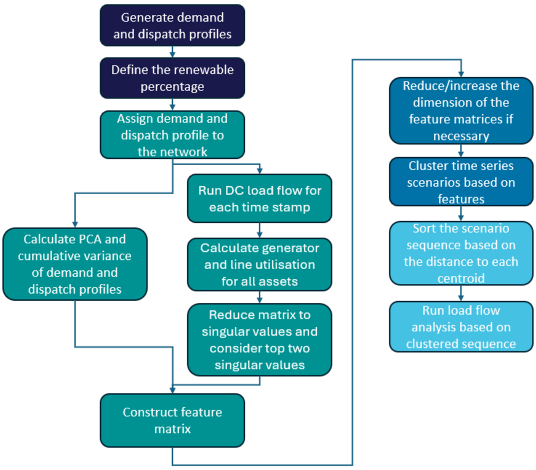
- **Demand/Dispatch data setup:** The demand and dispatch data are first collected by gathering different types of generators and loads data for one year. This data is then standardised. Following this, network information is extracted from the network model. Based on the power ratings and generation types, different profiles are assigned to the generators and loads, where the lower figure demonstrate an example of different generation profiles.



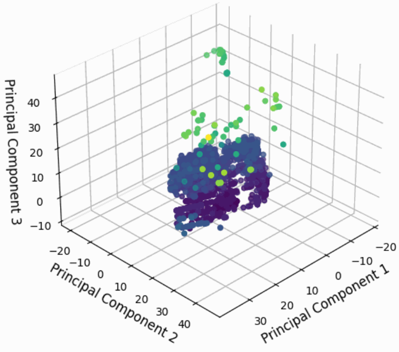
- **Test network setup:** The test network selection includes various predefined networks as well as an option for users to create a custom network. The available networks are: PandaPower GB Network, PandaPower Europe Network, IPSA IEEE 118 Network, and DigSILENT Texas Network. Additionally, users have the option to define and configure their own custom network based on specific requirements.
- **Simulation setup:** enabling or disabling dispatch clustering, choosing a dimension reduction method and a clustering method, specifying a network model and setting the renewable penetration, and configuring automation parameters. These settings ensure that the platform is adaptable to user preferences and requirements.

Method/Approach





Transformation from 3D to 2D



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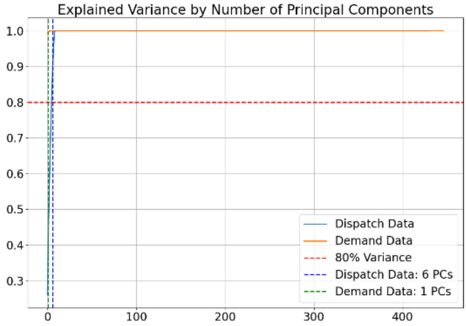
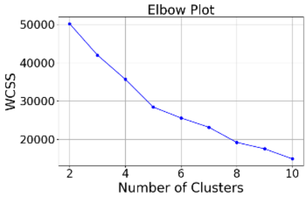
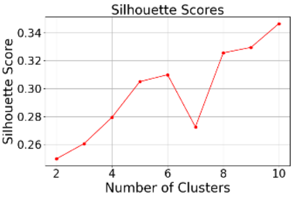
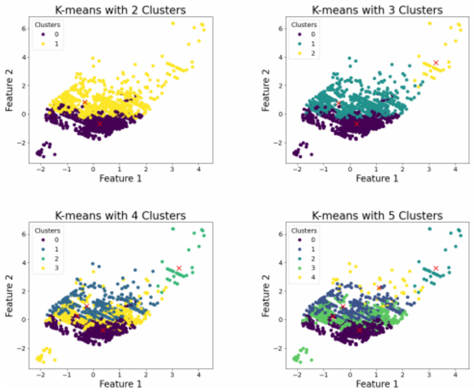
Experimental setup & test results









Discussion

Accumulated Variance of Principal Components:

- Left figure shows the cumulative variance of principal components.
- Exceeds 80% variance threshold with different numbers of principal components.
- Vertical dashed line at different number of PCs and horizontal line at 80% mark illustrate this.

Elbow Method for Optimal Clusters:

- The elbow plot shows a sharp decrease in WCSS from 2 to 5 clusters.
- Indicates 'elbow point' where additional clusters provide diminishing returns.
- Test 2, 3, 4, and 5 clusters to find the most meaningful segmentation.

K-means Clustering with PCA:

- The left animation shows k-means clustering results for 2, 3, 4, and 5 clusters.
- Clusters are distinct and colour-coded, with centroids marked by red crosses.
- Feature1 and Feature2 axes reveal variance distribution.
- Larger networks may show diverse patterns reflective of operational states.

Convergence Time Comparison:

- Table below presents convergence times for 8760 load flow simulations.
- Clustering reduces convergence time: 3 clusters improve time by 25.95% (1550.02s vs. 2093.30s).
- More clusters beyond two increase convergence time, peaking in 2093.30s with no clusters.
- Balance between cluster granularity and computational efficiency is crucial.

No. of clusters	Without clustering	2 clusters	3 clusters	4 clusters	5 clusters
Overall convergence time (s)	2093.30	1582.88	1550.02	1580.50	2056.46

Conclusion

- Use PCA to reduce features of dispatch and demand profile, capturing around 80% cumulative variance.
- Use SVD to extract first top 2 singular vectors of network topology.
- Load flow analysis based on clusters shows faster convergence compared to sequential analysis.
- Suitable for network planning under uncertainty, typically using 30mins day across 10 years.
- Test on more complex networks and optimise feature selection for further efficiency gains.

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