Control and Operation of Microgrids for Smart Distribution System

Dissemination No1. : Defining Three Distribution System Scenarios for Microgrid Applications in the 4th IEEE Conference on Energy Internet and Energy System Integration

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Motivation

- "**decarbonization**" and **higher performance** of the system are driving the ongoing revolution of distribution system
- "virtual power plant", "super grid", **microgrids** have been hypothesized for the solution, among which the last is the most promising
- **Conflict interests** and **uncertainties** from not only technological perspectives but also from regulatory necessitate the prediction of microgrid development

Objectives

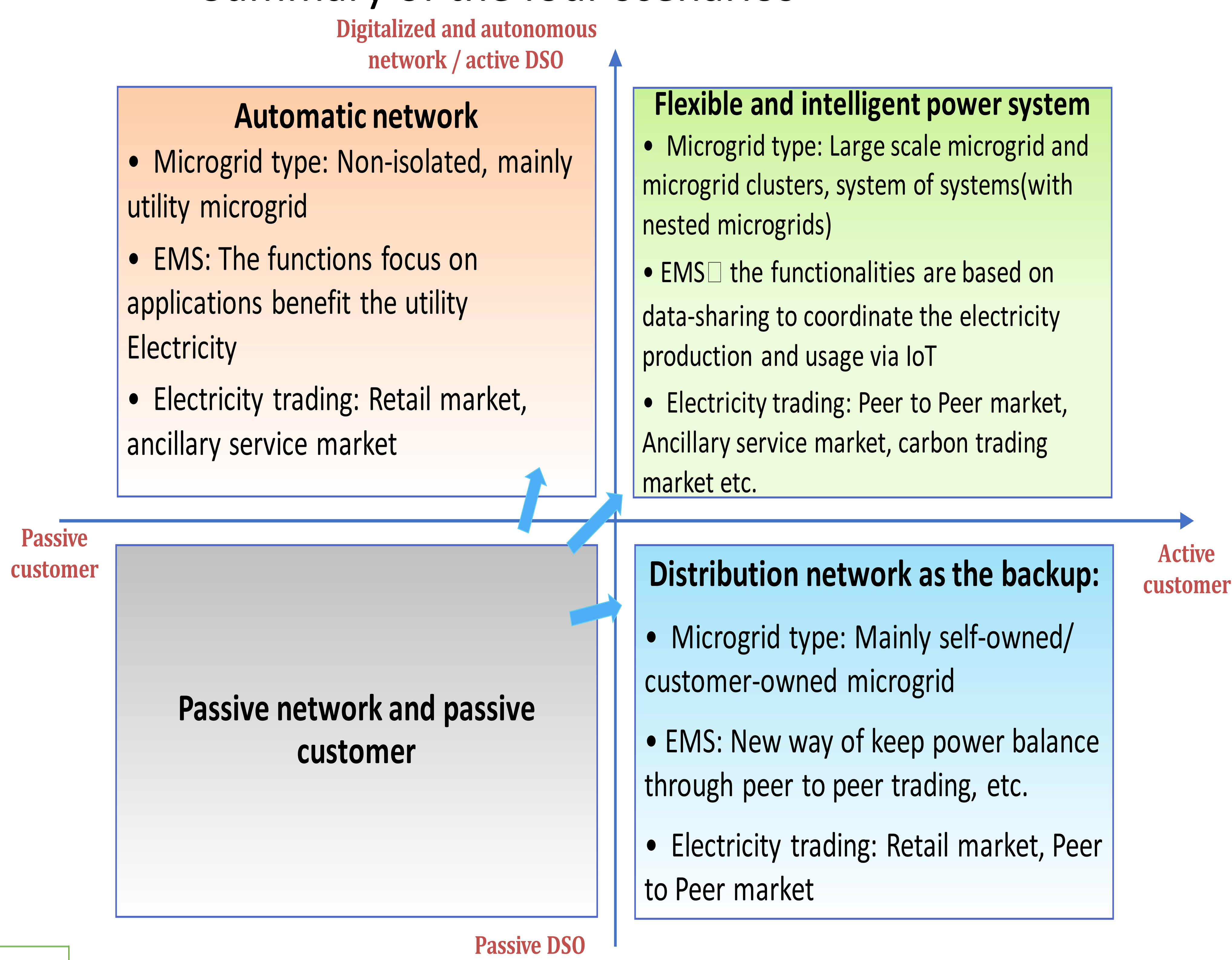
To identify **different scenarios** of future microgrid development in the distribution system to shed light on microgrid research

MARKET MODELS FOR DIFFERENT MG-DSO COORDINATION SCHEMES

Coordination Scheme	MG DSO interaction features	Remarks
Retail market model	The **main commodity is energy**. For microgrids, it will purchase energy deficit and sell the surplus (mainly from RES generation, some allow energy from storage to feedback to the grid). For DSO, it will buy energy from the RES from prosumer, mainly for carbon emission reduction.	Already exist. No real involvement of microgrid in terms of network operation responsibility. DSO uses **tariff design** (fixed pricing, dynamic pricing, capacity subscription, etc.) to incentivize the customer to help to mitigate the network stress
Ancillary market model	**DSO will purchase ancillary services from microgrids** in the form of the contractual agreement or maybe in real-time market, such as voltage regulation, congestion management, etc., to keep the stability and reliability of the network as well as to defer investment on network extension to accommodate more fluctuating renewable generation.	The flexibility achieved by microgrids through energy management (especially from energy storage utilization) can contribute to the ancillary service of required by DSO. It is still **a one-sided market**.
Wholesale market model	Both microgrids and DSO can participate in the wholesale market, especially the **spot market,** as sellers or buyers. They could compete with each other.	Microgrids participate in the wholesale market within VPP or third parties. Here the wholesale market is integrated with the local market. The wholesale market here is **a two-sided market**, but the microgrid's participation **relies on the third party**.
P2P market model	There can be little or no involvement from DSO, the **main participants are small players**, such as microgrids. **Microgrids exchange energy among themselves.** This market is a short-term local market, such as intraday or intra-hourly market.	The grid operation is achieved through utilizing local flexibility, the main market players are small players like microgrids or integrators. This is **a two-sided short-term local market**.

Results and findings

- Summary of the four scenarios



Methods/Approach

- A simple foresight method draws the scenarios into a 2*2 matrix considering two most critical uncertainties—the Distribution system operator (DSO) and the customer
- Two axes of the quadrant are from passive customers to active ones, and from passive to active DSO, respectively

Conclusions

- Three scenarios are identified and their use cases, energy management system features, and market models are projected
- A collective effort from different parties is needed for microgrid research to prepare better for the future

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Dissemination No2. : A Data-driven Approach to Grid Impedance Identification for Impedance-based Stability Analysis under Different Frequency Ranges

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Motivation and Objectives

- Use data to model the grid which can be embedded it into stability model
- Build a grid model that is high order and can represent different operation conditions
- Compatible with impedance stability analysis

Methods/Approach

Proposed Three-stage Data-driven Approach for Grid Impedance Identification

1 Grid impedance data preprocessing

- Non-intrusive measurements
- and/or
- Intrusive measurements
- and/or
- Simulation results

→ Multiple grid impedance data covering various operating conditions

2 Data clustering

- Impedance data processing
- Best cluster number determination
- \+
- K-means clustering

→ Reduced grid impedance representing different operating conditions

3 Grid impedance identification

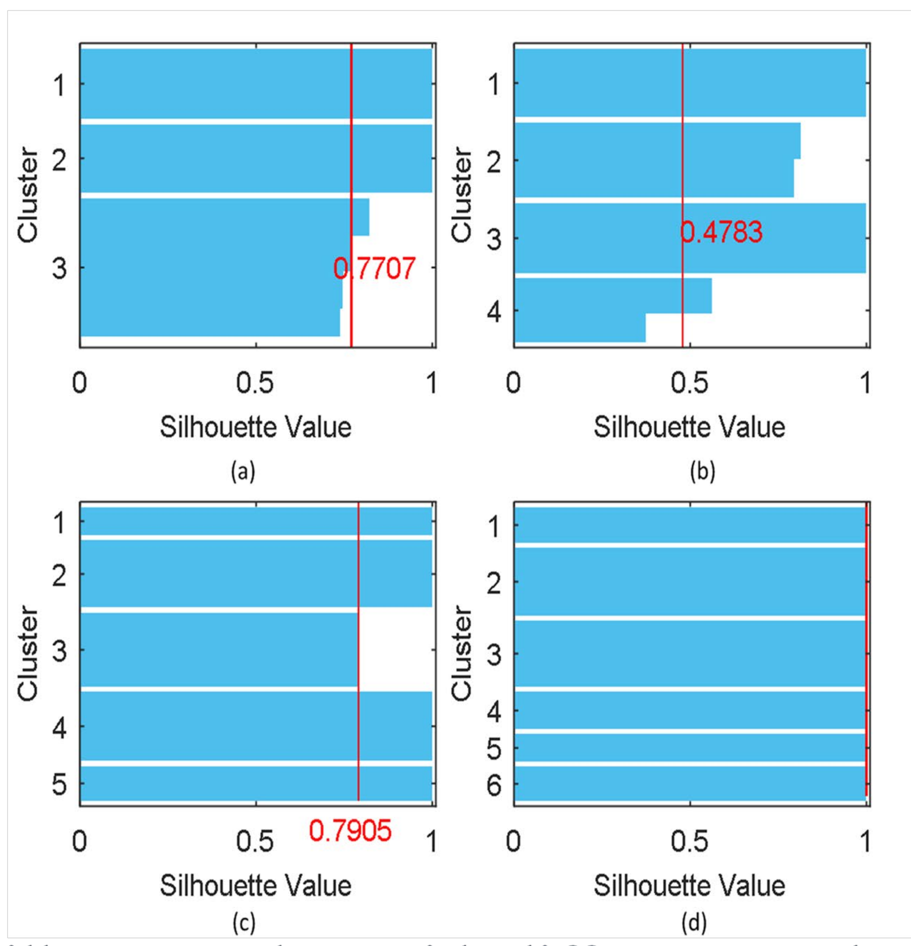
- Low frequency model from 0~200 Hz
- \+
- Medium frequency model from 200~800 Hz
- \+
- High frequency model from 800~1500 Hz

→ Grid model for impedance stability compatibility design

Results and findings

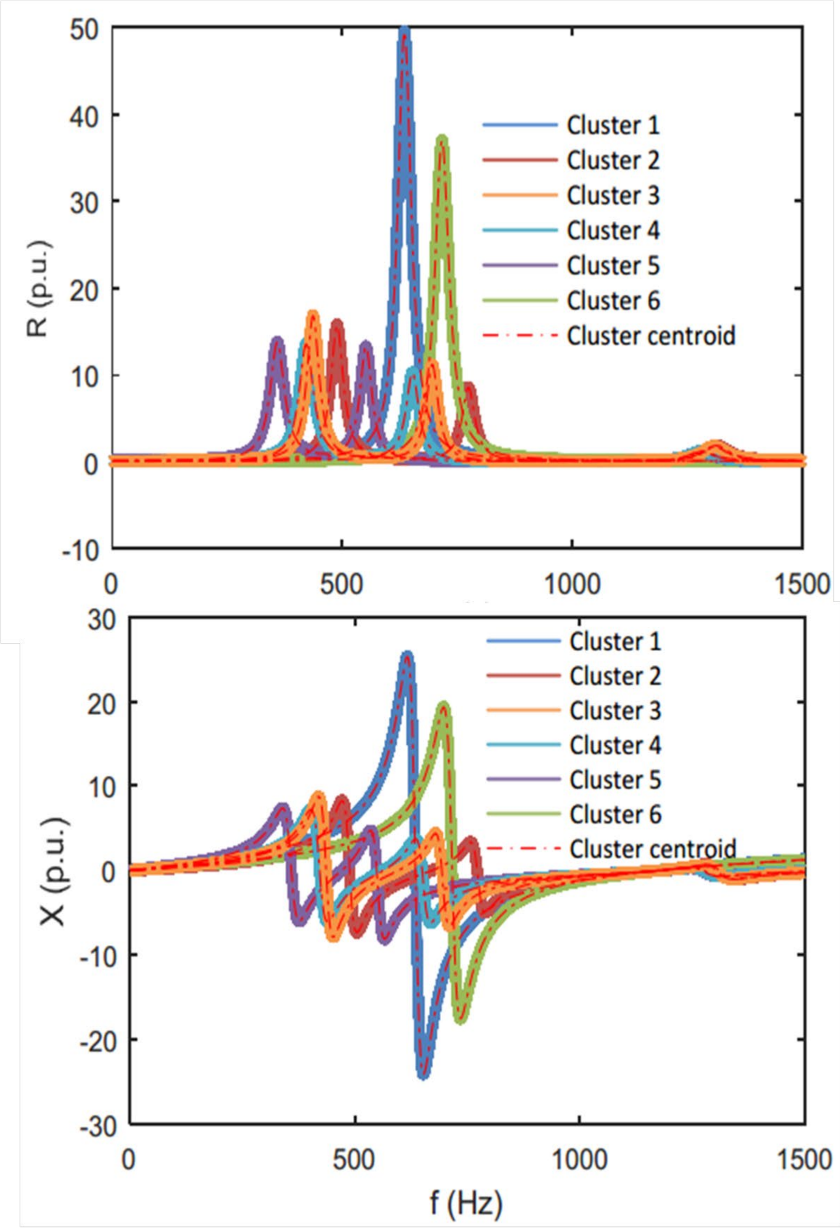
Grid impedance data clustering based on k-means clustering

$$s_i = \frac{b_i - a_i}{\max(a_i, b_i)} \Rightarrow s_{avg} = \frac{1}{n}\sum s_i$$



Silhouette plots with different number of clusters k: (a) with $k=3$, (b) $k=4$, (c) $k=5$, (d) $k=6$

The higher the average silhouette, the better the choice of number of the clusters is.

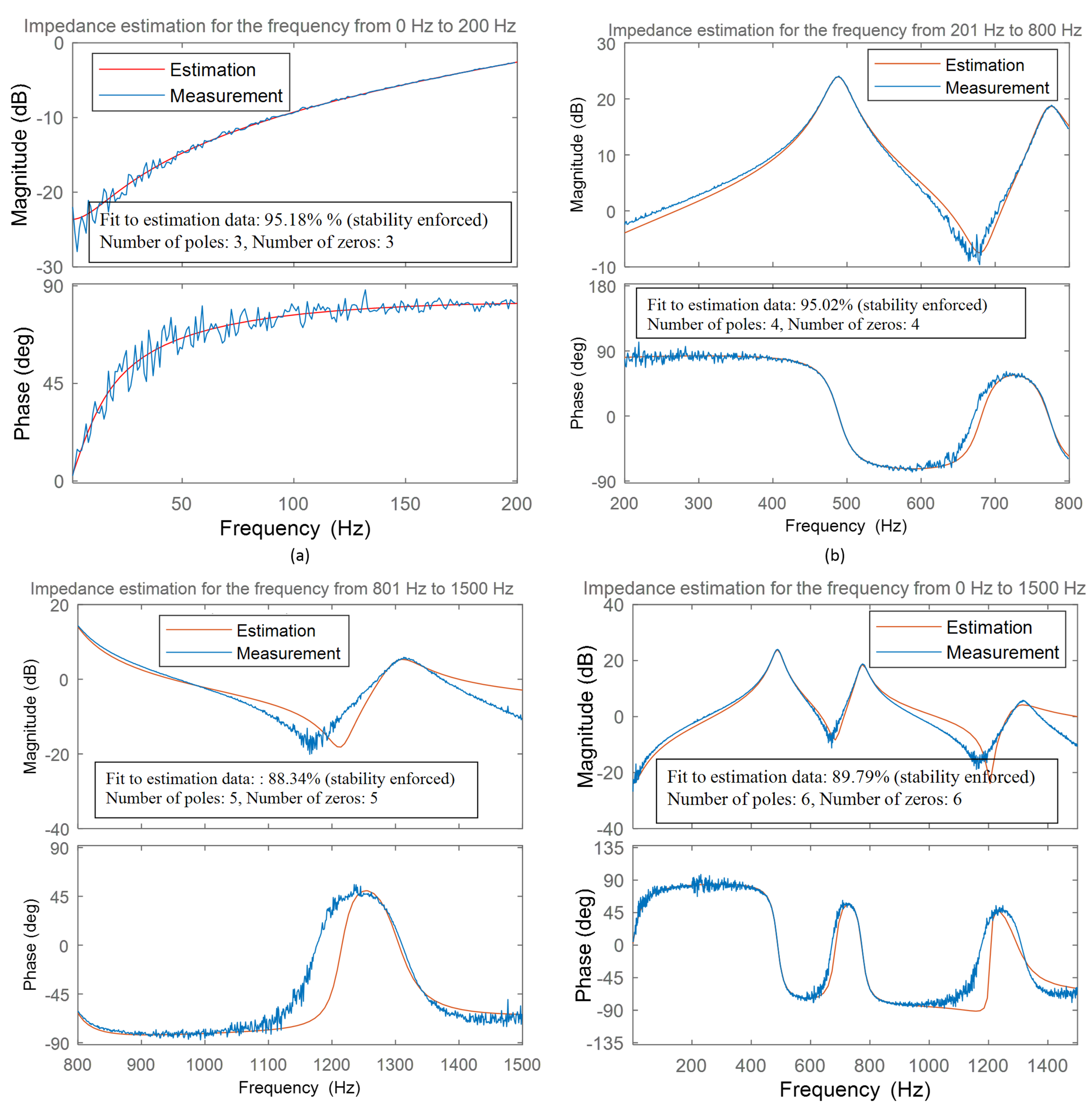


Grid impedance data partition results

a_i is the average distance from the vector to the other vectors in the same cluster as i, and b_i is the minimum average distance from the vector i to vectors in a different cluster, minimized over clusters.

$$Minimize \sum_{i=1}^{m} W(\omega_i)\left|G_r^*(\omega_i) - G(\omega_i)\right|^2$$

$$FIT = \left(1 - \frac{norm(G_r^*(\omega) - G(\omega))}{norm(G(\omega) - mean(G(\omega))}\right) * 100\%$$



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