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Optimal Placement of PMUs in Power Networks: *Modularity* meets *a Priori* Optimization

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Optimal PMU Placement (OPP)

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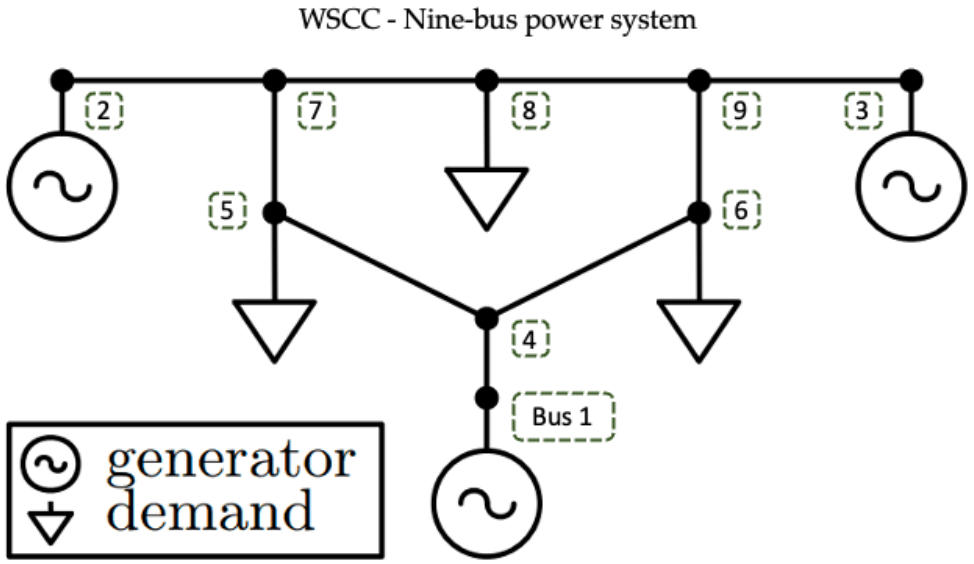
PMU Placement in Power Networks



Contributions for OPP in Power Network

- Nonlinear DAE power system model
- Incorporate loads from renewables
- Measurement noise and uncertainty
- Non-generator buses

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Building blocks for the OPP

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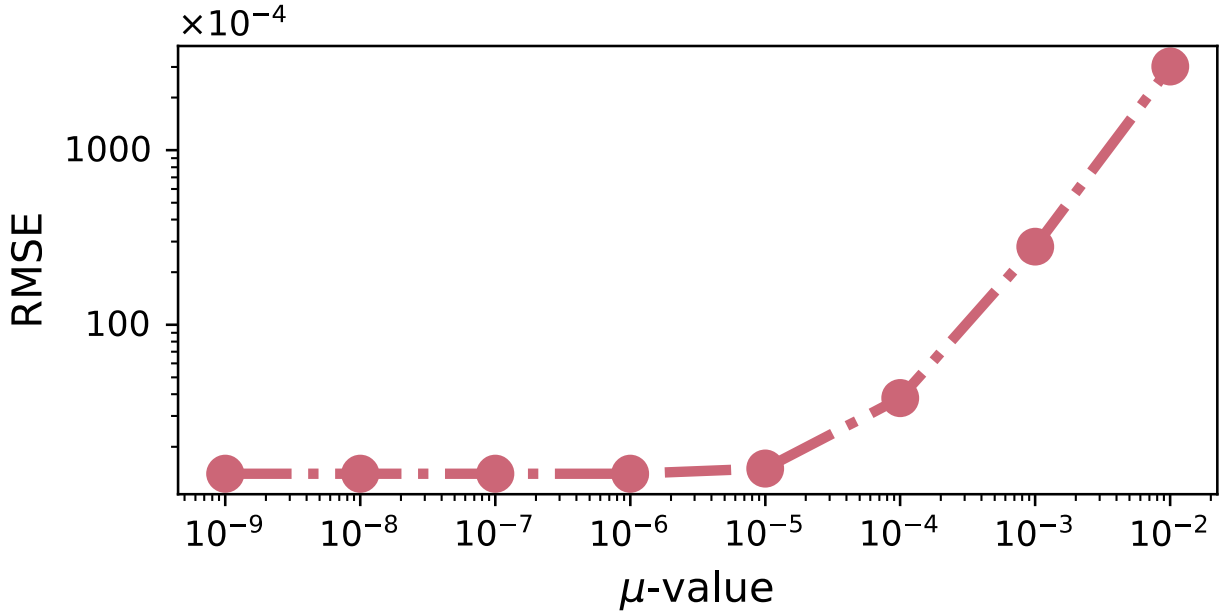
Step 1: Approximate System → Step 2: Discretization → Step 3: Observability Measures

Nonlinear differential algebraic equations (NDAE)

$$\textit{generator dynamics}: \quad \dot{\boldsymbol{x}}_d = \boldsymbol{f}(\boldsymbol{x}_d, \boldsymbol{x}_a, \boldsymbol{u})$$
$$\textit{algebraic constraints}: \quad 0 = \boldsymbol{g}(\boldsymbol{x}_d, \boldsymbol{x}_a)$$

$$\mu \dot{\boldsymbol{x}}_a = \boldsymbol{g}(\boldsymbol{x}_d, \boldsymbol{x}_a, \boldsymbol{u})$$



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A Priori Set Optimization

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Observability Matrix Under Modularity

Proposition 1: The observability matrix $\boldsymbol{W}_o(\cdot)$ can be written as a linear combination of individual observability contributions

$$\boldsymbol{W}_o(\cdot) = \sum_{i=1}^{N} \boldsymbol{W}_{o,i}(\cdot)$$

Resulting A Priori OPP

- Precomputed individual measures
- Minimal computing power
- Scalable

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OPP under A Priori Optimization

Test Case – IEEE-39

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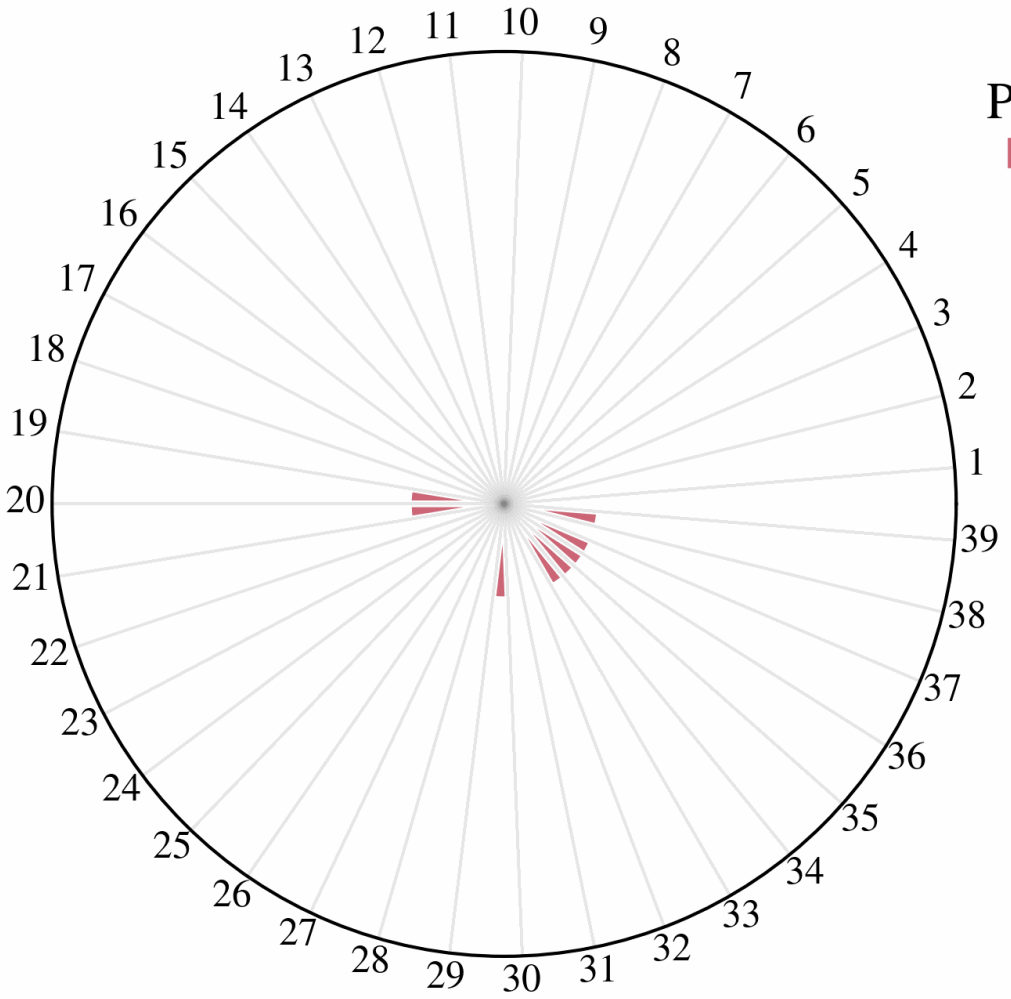

Modularity Preserved

Measurement Noise

Under Load/Renewable Change

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