Dynamic Model Reduction for Large-Scale Power Systems Using Wide-area Measurements

2020 CURENT NSF/DOE Site Visit and Industry Conference
Virtual
Nov. 2020

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Background and motivation
• Speed up dynamic simulation for large-scale power grids
• Improve the accuracy of coherency-based equivalents (obtained by DYNRED) using measurements
• Develop a PSO (Particle Swarm Optimization) based parameter tuning procedure for changing system conditions

Technical approach
• Derive the structure of the equivalents using DYNRED
• Apply PSO algorithm to tune the parameters of the equivalents with the objective of improving the matching of the dynamic responses with measurements
• Objective function
  \[ F_{ij} = 1 - \frac{\| f_{r,st} - f_{o,st} \|}{\| f_{r,st} - \bar{f}_{r,st} \|} \]
• Consider multiple scenarios during the optimization

Conclusion
• Developed a PSO based multiple-scenario parameter tuning procedure
• Carried out case studies in NPCC 140 bus and Texas system
• Improved the accuracy of the DYNRED based equivalents in representing dynamics of the study area
• Validated the effectiveness of the parameter tuning when system conditions change

Fig 1. Dynamic responses(DYNRED vs. PSO tuned)
Methodology

Initialization: \( s=1, n=1, \) and \( g=1; \) Set \( N, G, \) and \( S \)

Generate \( N \) groups of parameters

Perform simulation in Scenario-1

Record frequency measurements for a total number of \( T \) tie lines as \( f_{1,1}, f_{1,2}, \ldots, f_{1,T}, f_{2,1}, f_{2,2}, \ldots, f_{2,T}, \ldots, f_{S,T} \)

No

Yes

\( s=S? \)

No

Yes

Reduced model

Full model

\( F = \sum_{i=1}^{S} F_{i} / S \)

\( m=N? \)

No

Yes

Pick the parameters with the lowest \( \text{FIT} \)

\( g=G? \)

No

Yes

Parameter output

End

Perform \( S \) simulations in Scenario-1, Scenario-2, \ldots, and Scenario-\( S \), respectively.

Record frequency measurements for a total number of \( T \) tie lines as \( f_{1,1}, f_{1,2}, \ldots, f_{1,T}, f_{2,1}, f_{2,2}, \ldots, f_{2,T}, \ldots, f_{S,T} \)

Calculate \( F_{s} \) and \( F_{s} = S \)

Parameter output
Case Study

Testing scenario 1 (included in the training scenario)

Testing scenario 2 (not included in the training scenario)
Acknowledgements

This work was supported partially by the ERC Program of the National Science Foundation and DOE under NSF Award Number EEC-1041877 and the CURENT Industry Partnership Program.

Other US government and industrial sponsors of CURENT research are also gratefully acknowledged.