Damping Electromechanical Oscillations in Large-Scale Power Systems Using Intelligent Aggregated Control

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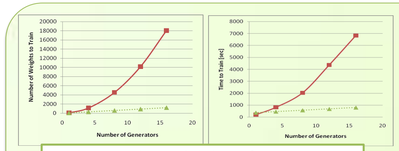
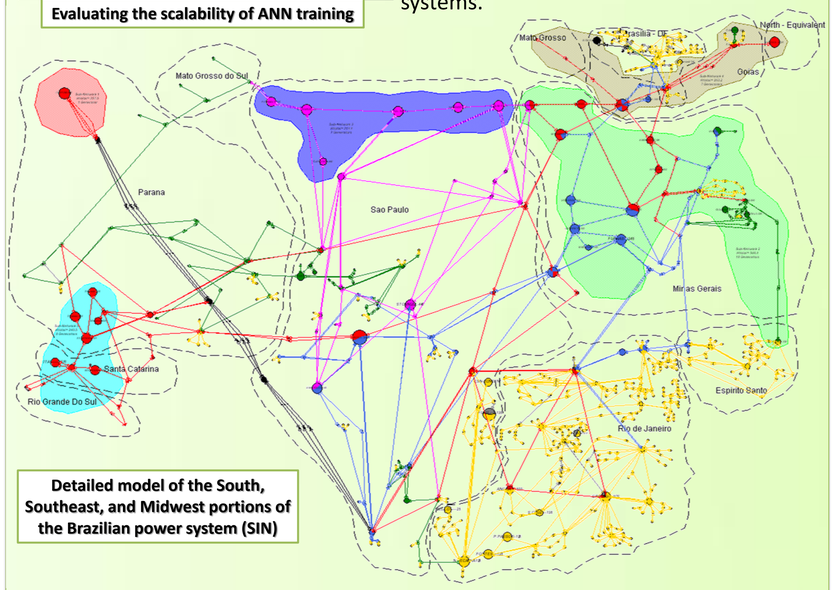
Poorly damped oscillations can constraint the safe operating region of power systems, prevent more economical operation, and increase the probability of wide-spread blackouts. Controllers capable of monitoring and injecting signals at multiple generating stations across the system can help mitigate these oscillations and improve overall performance. Methodologies for designing such controllers using approximate dynamic programming system aggregation techniques are proposed.



Evaluating the scalability of ANN training

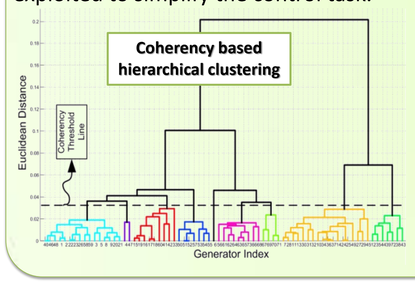
•The algorithms for training the ANN architectures typically used to implement intelligent controllers do not scale up well enough to handle large-scale power systems.



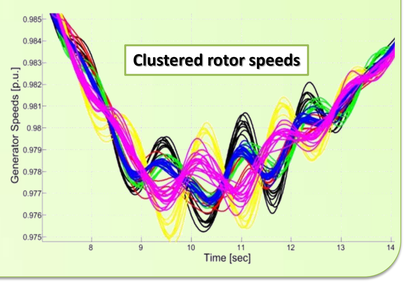
Detailed model of the South, Southeast, and Midwest portions of the Brazilian power system (SIN)

•Architectures like BIANNs and CNNs can offer improved scalability, but the methods to deploy them for closed-loop control are still under development.

•In the meantime, coherent behavior and system aggregation techniques can be exploited to simplify the control task.



Coherency based hierarchical clustering



Clustered rotor speeds

•Coherency based clustering **enables the partitioning of the system** into sub-networks.

•Each sub-network contains a set of generators that behave very similarly.

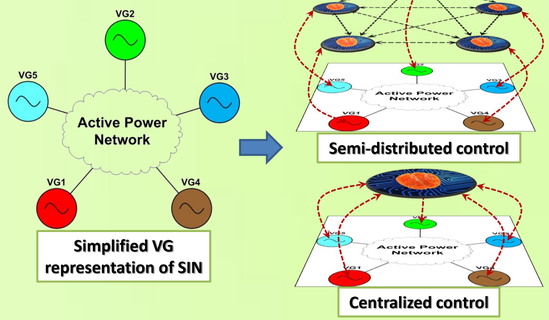
•Generators inside these sub-networks can then be aggregated online to create simplified representations of the system using the "Virtual Generator" (VG) concept.

•Only sub-networks with a high impact on the system dynamics are considered.

•These sub-networks are identified by their high inertia relative to the total system inertia

•The geographical distribution of the sub-networks confirm the clustering results.

Geographical locations of important sub-networks



•Controllers can now treat large portions of the system as if they were a single generator.

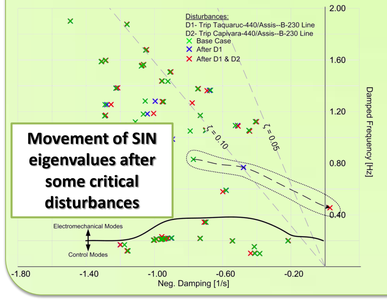
•The slower oscillations are preserved and the faster ones are ignored.

•Centralized and semi-distributed controllers are being explored.

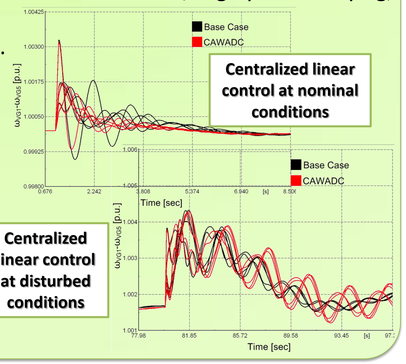
•VGs help with scalability, but that is not enough.

•In spite of the simplifications, the system is still non-linear, highly time-varying, and affected by stochastic disturbances.

•Conventional control is not robust enough.



Movement of SIN eigenvalues after some critical disturbances

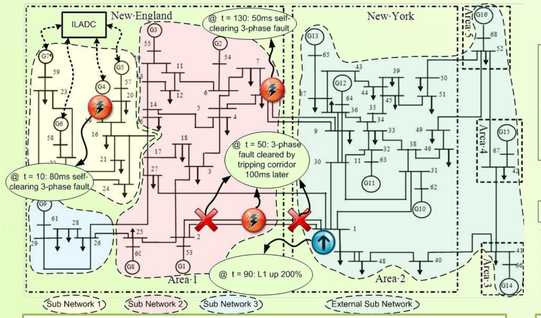


Centralized linear control at nominal conditions

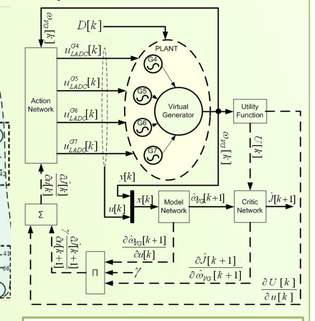
Centralized linear control at disturbed conditions

•An intelligent control approach is first tested on a medium size system (68-bus)

•Heuristic dynamic programming is used for controller adaptation



68-bus 10-machine New England/New York benchmark system



HDP+VG based intelligent controller

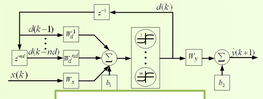
•An object oriented library has been developed in C++

•Capable of implementing and training a large class of feed-forward and recurrent ANN architectures

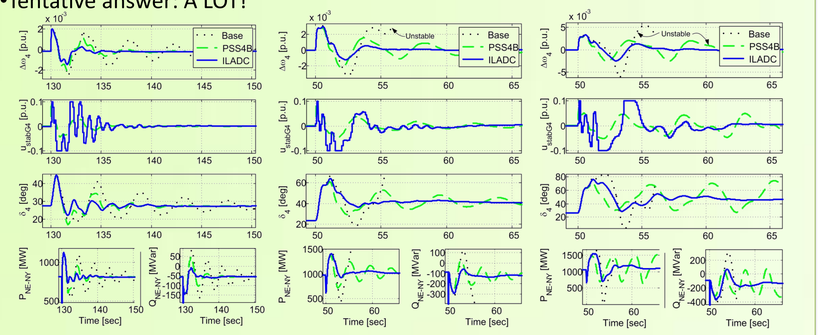
•The globally recurrent neural network is used

•Simulations prove into the question: how much can an intelligent controller help?

•Tentative answer: A LOT!



ANN Architecture



•Current efforts focus on implementing the centralized and semi-distributed intelligent aggregated control approach on the Brazilian system

•The centralized approach is straightforward, but the semi-decentralized approach requires multi-agent learning so the path forward is not as clear

[1] D. Molina, G. K. Venayagamoorthy, J. Liang, R. G. Harley, "Intelligent local area signal-based damping of power systems using virtual generators and approximate dynamic programming," *IEEE Trans. on Smart Grid, under review*

[2] D. Molina, J. Liang, G. K. Venayagamoorthy, and R. G. Harley, "Virtual generators: simplified online power system representations for wide-area damping control," 2012 IEEE PESGM, July 2012

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