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A Robust Control Technique for Damping Low Frequency Oscillations in the WECC

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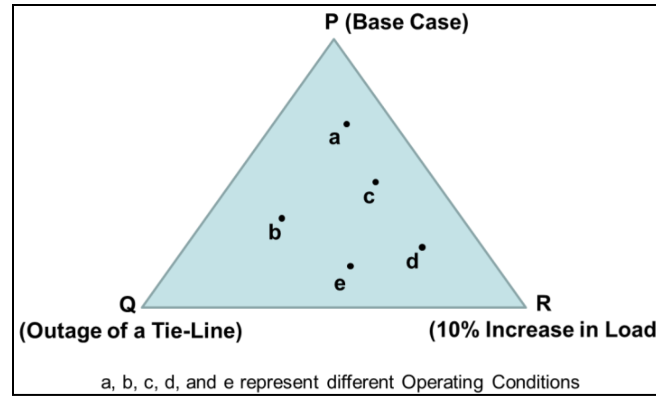
Project Objective

- Design a robust controller for damping low frequency oscillations in the WECC
- Main Characteristics of the Control:
  - Ensure a pre-specified percentage of damping on all the low frequency modes of oscillations
  - Provide more damping to the relevant inter-area modes of oscillations

Control Logic

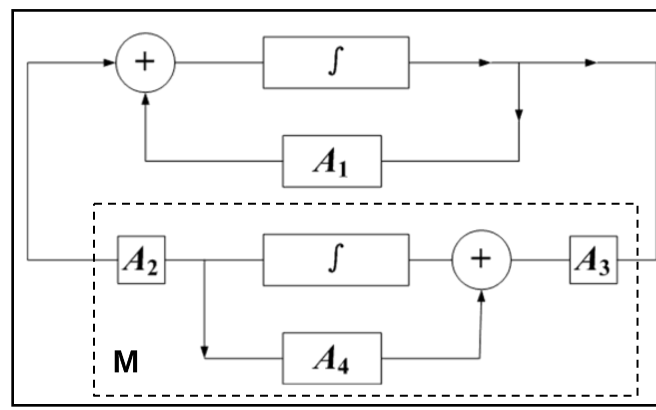
Linear Matrix Inequalities (LMIs) [1-2]

Developed a polytopic system model capable of simultaneously optimizing a variety of operating conditions



Selective Modal Analysis (SMA) [3]

Reduced size of the system without affecting relevant dynamics



Motivation for Proposed Technique

Need:

(Traditional SMA+LMI) optimization still too complex for practical applications [4]

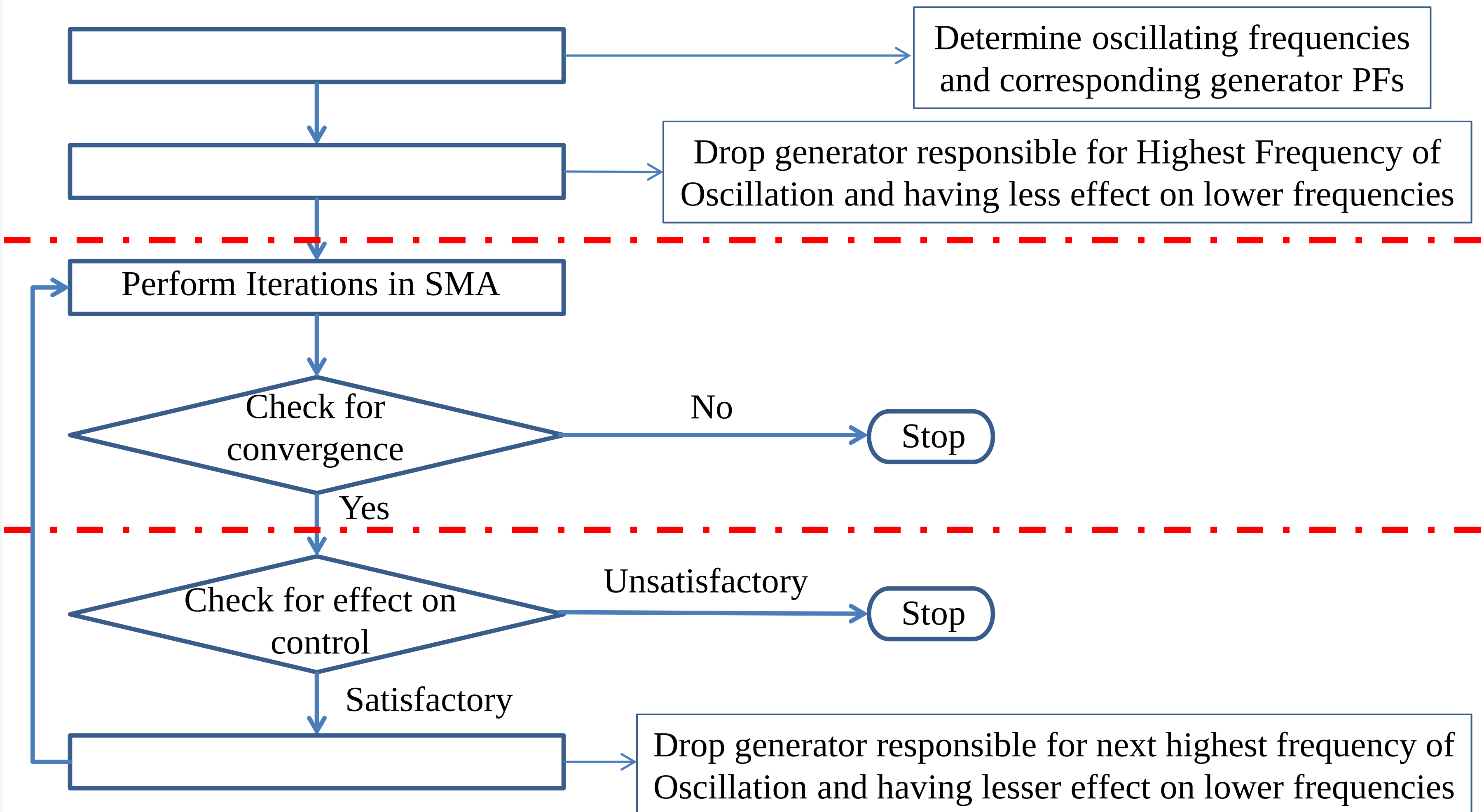
Goal:

Reduce size of the system further

Methodology followed:

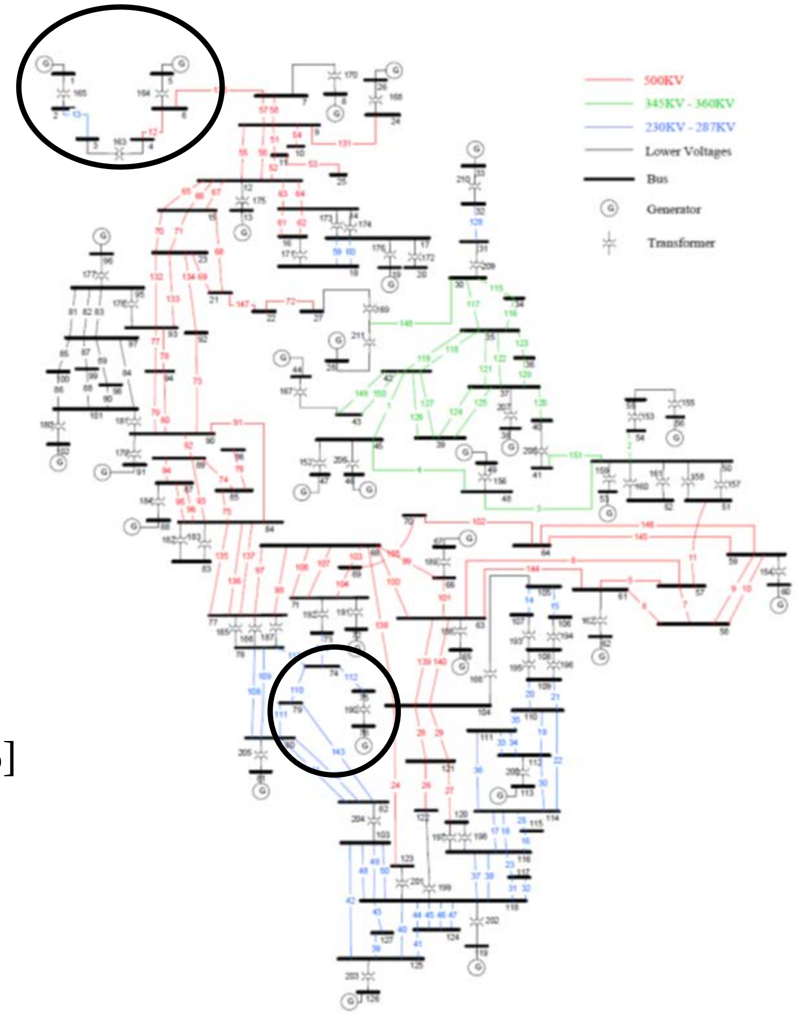
Extend SMA to reduce the size of the system to the relevant modes of oscillation

Flowchart of Proposed Technique [5]



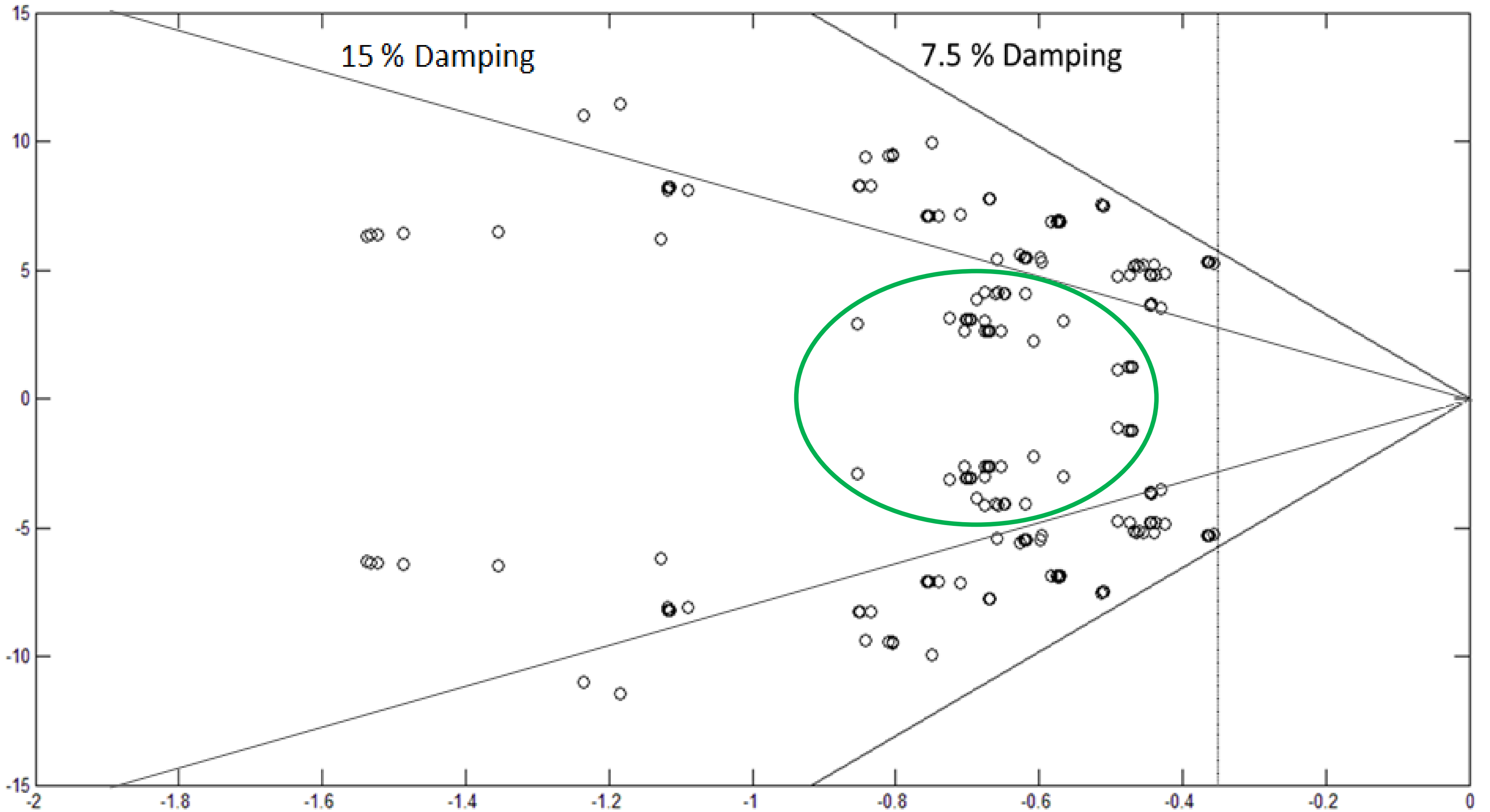
Control Devices and their Locations

- HVDC Lines*
  - Celilo and Sylmar (PDCI)
  - Inter-mountain and Adelanto
- SVCs*
  - Adelanto
- Energy Storage Devices (ESDs) [6]
  - Two in the Canada Equivalent
  - One in the Los Angeles County



* Already present in the system

Damping using 6 Controls

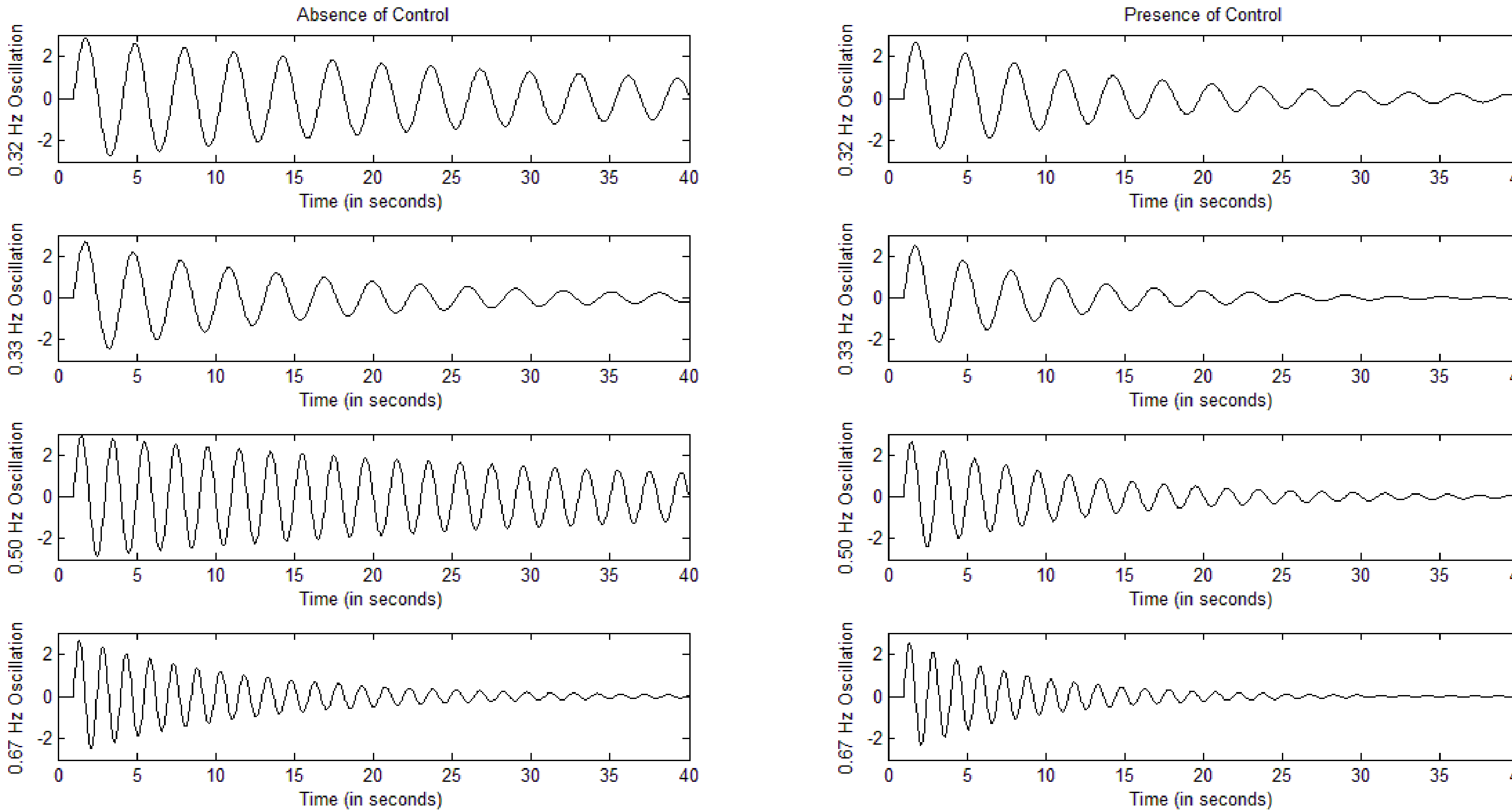


Comparison Results (127 Bus Model)

	Traditional SMA + LMI Control	Proposed Algorithm + LMI Control
System Size (A_1)	56×56	42×42
Size of individual LTI system	86×69	65×55
Size of Polytopic System	86×561	65×449
Size of Closed Loop System	86×513	65×401
CPU Time* (seconds)	$\mathbf{5435.701939}$	$\mathbf{1543.530256}$

* Computations performed on an Intel (R) Core™ i5 Processor having a speed of 2.40 GHz & an installed memory (RAM) of 5.86 GB

Extension of Control to Enhanced California Model [7]



Summary & Future Work

- Integrated form of control – improved damping
- Robust controller – applicable over a wide range of operating conditions
- Future Scope of Work:
  - Test different contingencies
  - Increase size of polytopic system
  - Combine polytopes

References

[1] S. Boyd, L. El Ghaoui, E. Feron, and V. Balakrishnan, *Linear Matrix Inequalities in Systems and Control Theory*, SIAM books, Philadelphia, 1994.

[2] P. Gahinet, A. Nemirovski, A. J. Laub, M. Chilali, *LMI Control Toolbox for use with MATLAB*, The Math Works, Inc., USA.

[3] G. C. Verghese, I. J. Perez-Arriaga, and F. C. Schweppe, "Selective modal analysis with applications to electric power systems, Part II: The Dynamic Stability Problem", *IEEE Trans. PAS*, Vol. 101, No. 9, pp. 3126-3134, Sept. 1982.

[4] J. Ma, S. Garlapati, and J. Thorp, "Robust WAMS based control of inter area oscillations", *Electric Power Components and Systems*, Vol. 39, No. 9, pp. 850-862, May 2011.

[5] Anamitra Pal, and James S. Thorp, "Co-ordinated control of inter-area oscillations using SMA and LMI", presented at the *IEEE PES Conference on Innovative Smart Grid Technologies (ISGT 2012)*.

[6] Y. Zhang, and A. Bose, "Design of Wide-Area Damping Controls for Inter-area Oscillations", *IEEE Trans. Power Syst.*, Vol. 23, No. 3, pp.1136-1143, Aug. 2008.

[7] Anamitra Pal, "Damping low frequency oscillations in the WECC," *Final Project Report, Public Interest Energy Research (PIER) Program, TRP-08-06*, prepared for California Energy Commission by Virginia Polytechnic Institute and State University, Blacksburg, Virginia, Nov. 2011.

Software used: MATLAB, DSA Tools, PSLF