Overlapping Decomposition of Load Flow Jacobian for Static Voltage Stability Indicator in Interconnected Power System

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Problem Posing

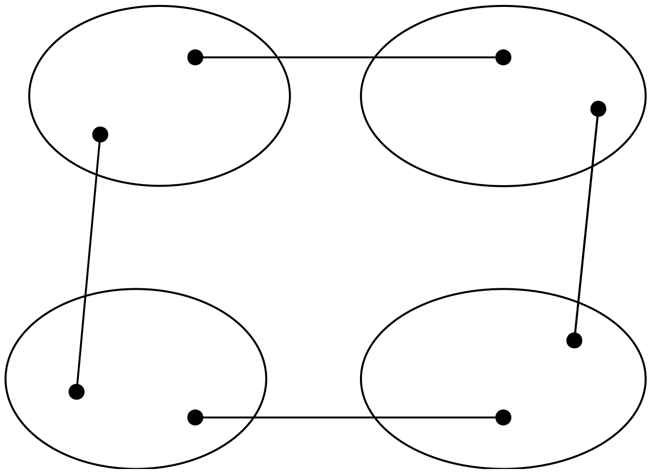
- **Needs for monitoring the interconnection based on QIs essential for deciding the severity of the operating mode in a decentralized way**
- **Static voltage stability is an important and starting point for research in power system stability**
- **How to monitor static voltage stability from some practically effective and decentralized QIs?**

Problem Solving: Model Review

- **DAE Equations-> ODE Equations-> Linearized Model**
  - **Monitoring load flow Jacobian determinant can detect a possible dynamic instability under certain assumptions [1]**
- **Load level producing zero determinant can serve as an upper bound of steady-state stability**
- **Load flow Jacobian determinant is a main QI for static voltage stability**

Decomposition of Load Flow Jacobian

- **Properties of load flow Jacobian**



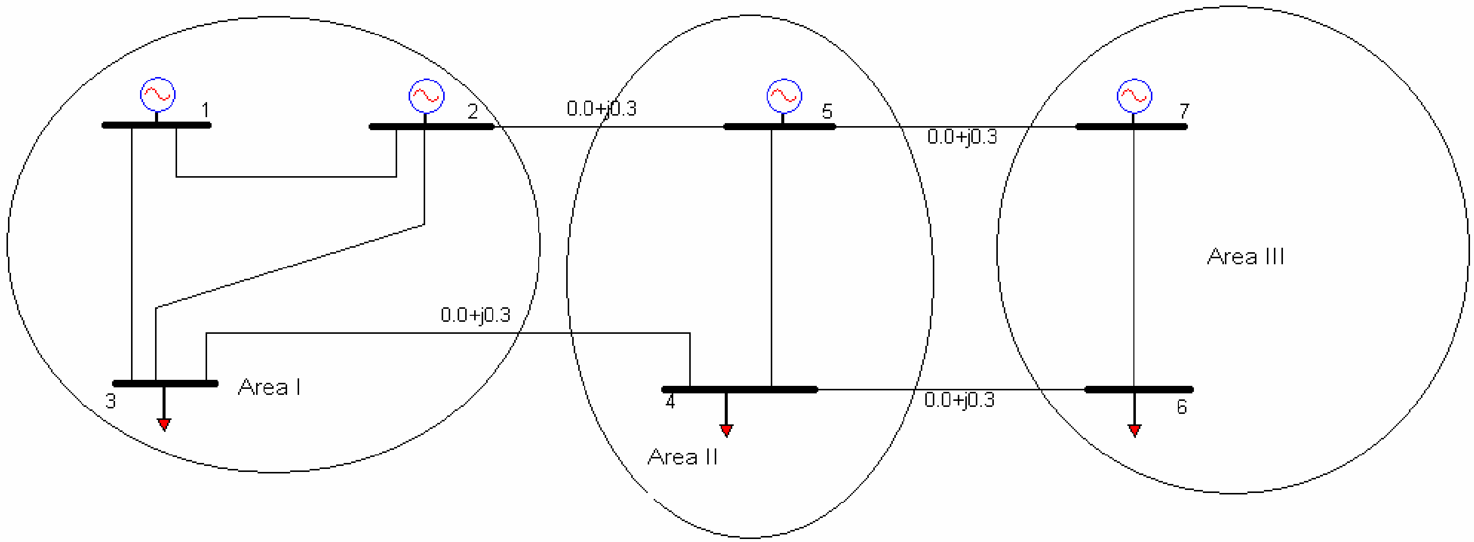
$$J = \begin{bmatrix} J_{I-I} & J_{I-II} & J_{I-III} & J_{I-IV} \\ J_{II-I} & J_{II-II} & J_{II-III} & J_{II-IV} \\ J_{III-I} & J_{III-II} & J_{III-III} & J_{III-IV} \\ J_{IV-I} & J_{IV-II} & J_{IV-III} & J_{IV-IV} \end{bmatrix}$$

$$J_{I-IV} = 0, J_{II-III} = 0$$

$$J_{III-II} = 0, J_{IV-I} = 0$$

- **By overlapping decomposition of J with tie-line buses overlapped, one can effectively get a probably promising decentralized indicator of static voltage severity**

Example: 7 Bus System



An interconnected power system

All intra-area transmission lines are with impedance of **0+j0.1**

Bus 1 is a slack bus, bus 2, 5, 7 are P-V buses, and bus 3,4,6 are P-Q buses.

Load at bus 3, 4 and 6 have same power factor of 0.995

Keep increasing load at bus **6**, while keeping all the other loads constant

Simulation Results

- **By disjointly partitioning load flow Jacobian**

Load level (load at bus 6)	Minimum eigenvalue of system load flow Jacobian	Minimum eigenvalue of area-based partitioned block matrices
250 + j25 MVA	0.4931	2.0686
285 + j28.5 MVA (close to collapse)	0.2222	1.1355

- **By overlapping decomposition of load flow Jacobian**

Load level (load at bus 6)	Minimum eigenvalue of system load flow Jacobian	Minimum eigenvalue of overlapping decomposed block matrices
250 + j25 MVA	0.4931	0.4931
285 + j28.5 MVA (close to collapse)	0.2222	0.2222

Observation

- **Simple block partition of system load flow Jacobian does not effectively indicate static voltage severity**
- **By overlapping decomposition of load flow Jacobian, the minimum eigenvalue of block matrices can serve as an indicator of system static voltage severity**
- **Only tie line buses' entries in system load flow Jacobian matrix are needed to exchange between neighboring areas**

Conclusion

- **Our work proposes a possibly promising indicator for static voltage stability**
- **This indicator could be achieved in a decentralized way. Only a small piece of information is needed to exchange between neighboring areas**
- **More theoretical work is required for justification of guaranteed performance of this method**

Key References

- **[1] P.W. Sauer, M.A. Pai, "Power system steady-state stability and the load-flow Jacobian", IEEE Transactions on Power Systems 1990**
- **[2] M. Ilic, E. Allen et. al, "Preventing Future Blackouts by Means of Enhanced Electric Power Systems Control: From Complexity to Order", IEEE Proceedings 2005, pp 1920-1941**

Thank You!