Optimal Allocation of Wind Generation Subject to Voltage Stability Constraints

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Introduction

- Increasing penetrations of wind will displace conventional plant
- Pattern of wind capacity allocation and reactive power control scheme of wind farms may influence the voltage stability of the system
- Control of reactive power generation in wind farms may improve voltage stability of the system[1]
- Loadability margin (LM), distance of the normal operating point to voltage collapse point, is a criteria used to assess the voltage stability of the system

Objective:

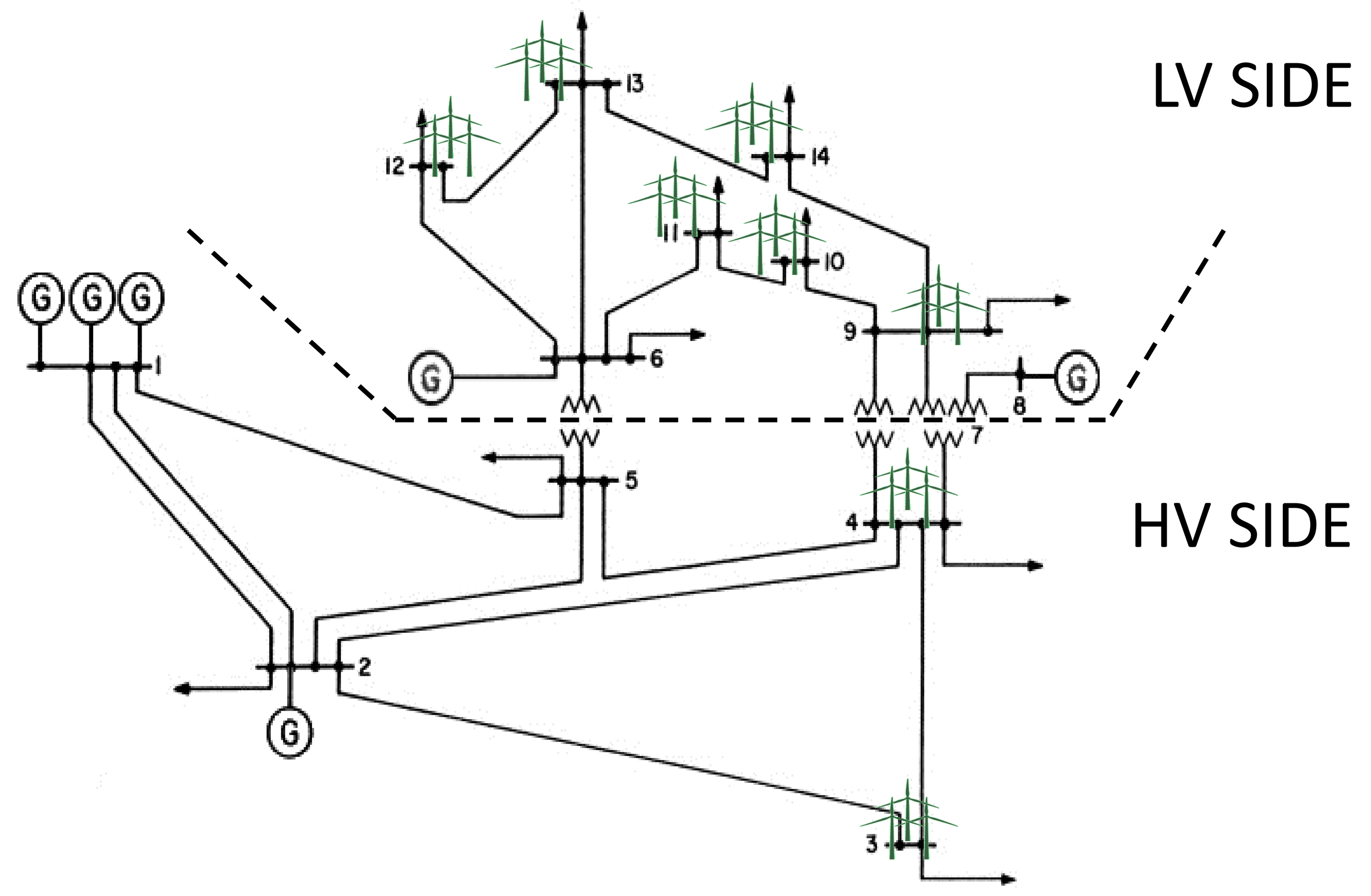
➢ **Investigate the effect of the pattern of wind capacity allocation and reactive power control scheme on steady state small disturbance long term voltage stability**

Methodology

- Loadability margin added to AC optimal power flow using the enhanced two sets of variables approach
- 10 (wind capacity factor) X 8 (demand level) = 80 scenarios
- Unit commitment → Least loadability margin = 31%
- Two objective functions:
  1) $Max\ P_{wind\_capacity}$: Max wind capacity
  2) $Max\ LM_{HV}^{Min}$: Max voltage stability at HV buses

Test Case

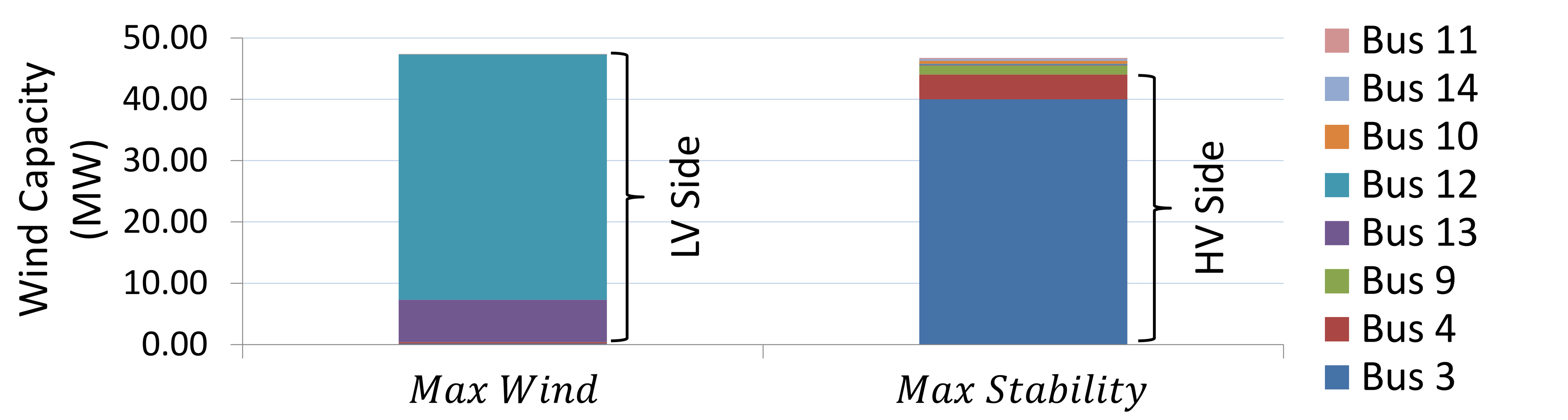
- Modified IEEE 14 bus network
- 8 candidate buses for wind capacity allocation
- Automatic Voltage Regulation (AVR), $V^{sp} = 1\ p.u.$
  - → Conventional generators
  - → Wind farms in HV buses (buses 3 and 4)



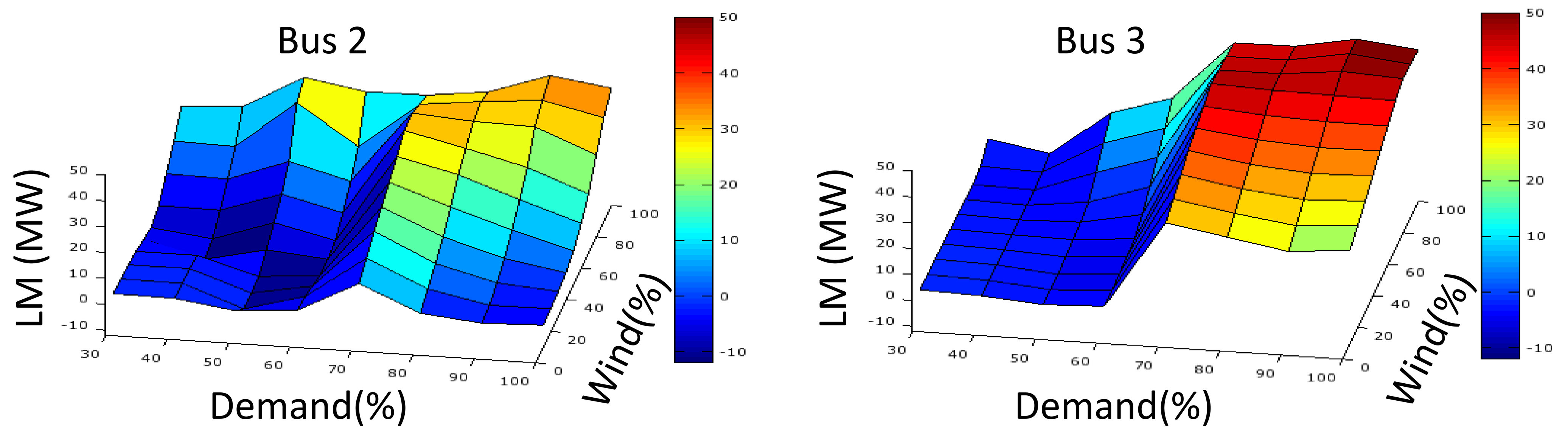
[1] E. Vittal, M. O'Malley, and A. Keane, "A Steady-State Voltage Stability Analysis of Power Systems With High Penetrations of Wind," *IEEE Transactions on Power Systems*, vol. 25, no. 1, pp. 433-442, 2010.

Results

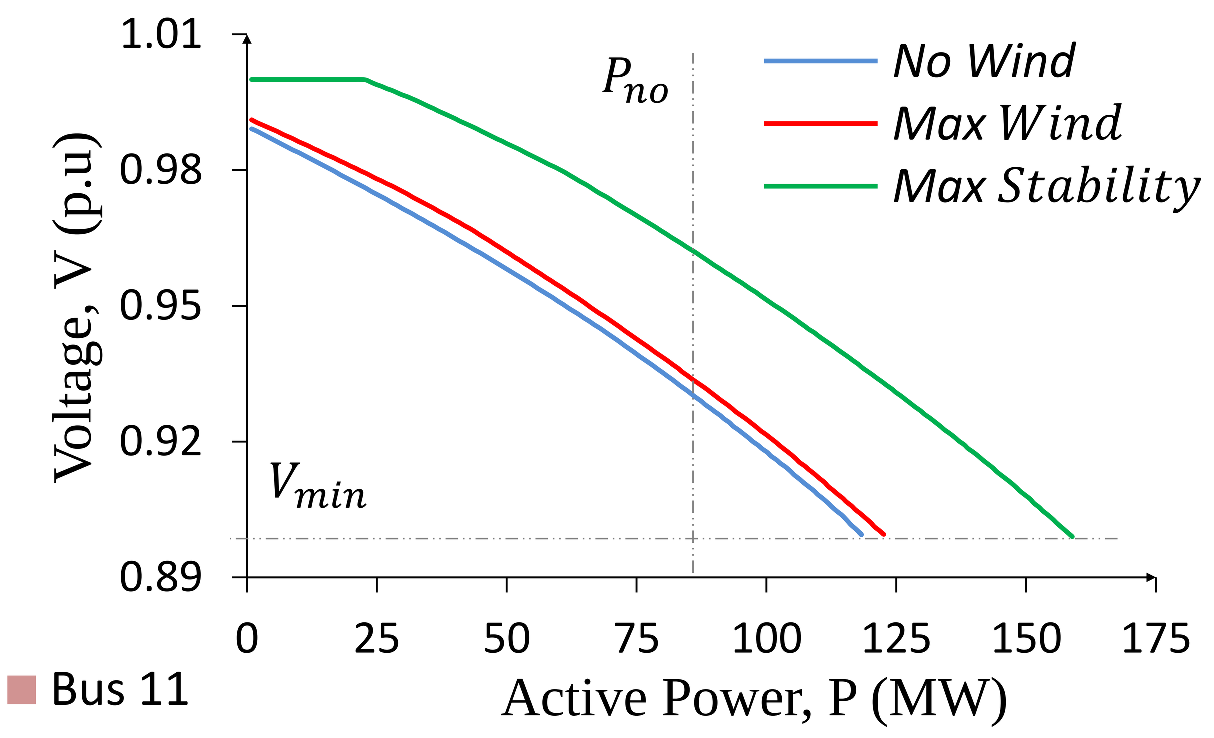
- Almost equal total wind capacity with both objective functions
- Different pattern of wind capacity allocation:
  - $Max\ Wind$: Mostly in LV side of the system
  - $Max\ Stability$: Mostly in HV side of the system
- Significant difference in terms of stability:
  - $Max\ Wind$: LM_{HV}^{Min} = 32.45% $Max\ Stability$: LM_{HV}^{Min} = 58.19%

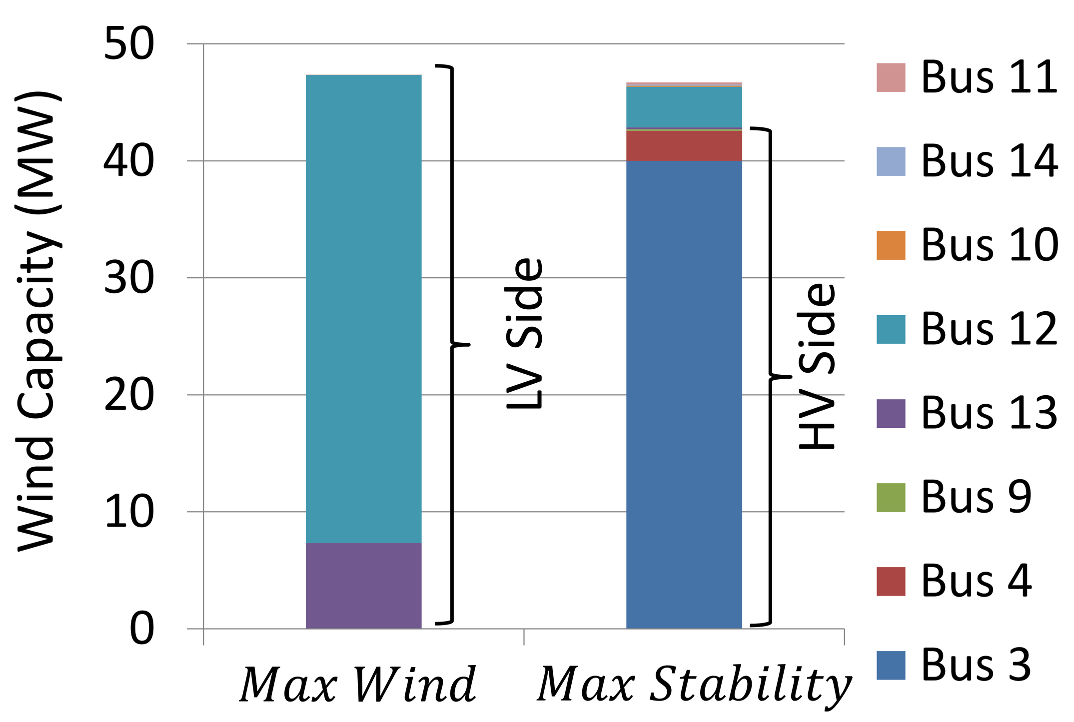


- $Max\ Wind$ vs. $Max\ Stability$: Improvement of stability at buses 2 and 3 with demand levels higher than 70%



- $No\ Wind$ vs. $Max\ Wind$:
  Slight stability improvement @ bus 3
- $No\ Wind$ vs. $Max\ Stability$:
  Large stability improvement @ bus 3





- Application of voltage control to wind farms in LV side:
  - No significant change in the wind capacity allocation pattern
  - Improved stability (LM_{HV}^{Min} = 50.53%) in $Max\ Wind$ case

Conclusions

- **Objective function influences the pattern of wind capacity allocation. This highlights the importance of AC optimal power flow formulation.**
- **Allocation of wind capacity to critical buses didn't alter total wind capacity allocated significantly while its benefits in terms of voltage stability are evident.**
- **Application of voltage control to wind farms may increase voltage stability in the HV side of the system. This emphasizes the importance of reactive power control.**

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