

# Wind Integration Issues

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# Wind Integration Issues

- Parsing the problem is the essential first step.
- Time frame of interest is the key variable
- Several “2nd Generation” studies are ongoing (CA, MN, NY, Denmark, Germany, Spain)

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| <b>Time Frame</b>         | <b>Less than 4 sec</b>                | <b>Seconds to 5 Minutes</b>       | <b>Minutes to Hours</b>            | <b>Hours to Days</b>                 | <b>Planning</b>                     |
|---------------------------|---------------------------------------|-----------------------------------|------------------------------------|--------------------------------------|-------------------------------------|
| <b>Key Issue</b>          | Voltage control, disturbance response | Frequency control, AGC            | Unit dispatch/load following       | Unit commitment/Operational planning | Capacity accreditation              |
| <b>Key Concept</b>        | Grid Code for VAR support, LVRT       | Square root of sum of the squares | Liquid spot market/telemetry/SCADA | Forecasting                          | ELCC                                |
| <b>Cost Range, \$/MWH</b> | 0 –5% of project capital cost         | 10-20 cents/mwh                   | 0-\$1/mwh                          | \$1-4/mwh                            | Generally less than capacity factor |

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## Conclusions and Observations

- Wind integration costs are de minimus (less than \$1/mwh) at “low” penetration rates, moderate (less than \$4/mwh) at “moderate” penetration rates, and mitigatable at “high” penetration rates. The shape of the cost curve for any particular system is flat with a hockey stick inflection point beyond “moderate” penetration.
- The value of “low,” “moderate,” and “high” depends (in order of importance) on the following variables: size of the system, type of tariff, stiffness of the grid, flexibility of the other generation in the portfolio. For an “average” system, low is less than 10% penetration, moderate is 10-20%, and high is greater than 20%.
- The real operational issues are generally over-generation in minimum load hours, not variability, uncertainty, or low generation on peak.
- Mitigation is generally taken in following order: Software/IT/forecasting, dump energy, transmission investment, other generation investment, and, finally, storage.