Improving Grid Stability Through Integrating Energy Storage in Utility Scale Photovoltaic Plants

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Agenda

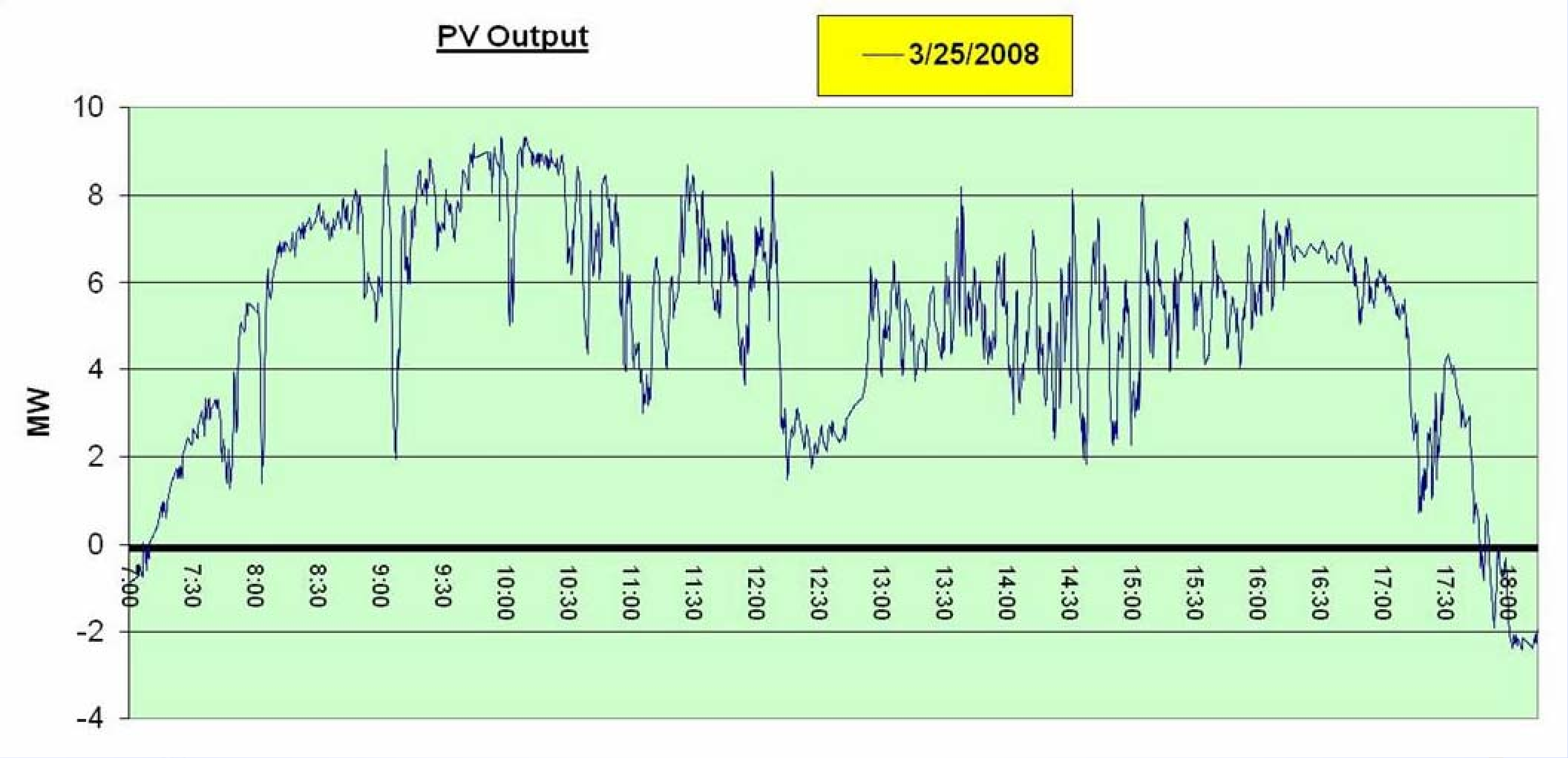
- Renewable Energy Impact in System Stability
  - Cloud induced power fluctuation in PV plants
- Energy Storage as a Solution
- Integration of Battery Systems in PV Plants
  - Centralized configuration vs. Distributed configuration
- Design and Financial Considerations

Renewable Energy Impact in System Stability

- Nature of renewable energy– intermittent and non-dispatchable
- Case of Cloud induced power fluctuation in PV plants
  - Ramp-up / Ramp-down power output
  - Power output reduction to 25%
  - Several times a day
  - Difficult to predict

Case of Cloud induced power fluctuation in PV plants

Power Output ramps from a 10 MW PV plant in a cloudy day



Source: Accommodating High Levels of Variable Generation, NERC, April 2009

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System Stability

- Requirement for additional system regulation capacity (e.g. spinning reserves)
- Impact depends on grid system characteristics
- More important with high PV penetration and larger PV plants

Energy Storage as a Solution

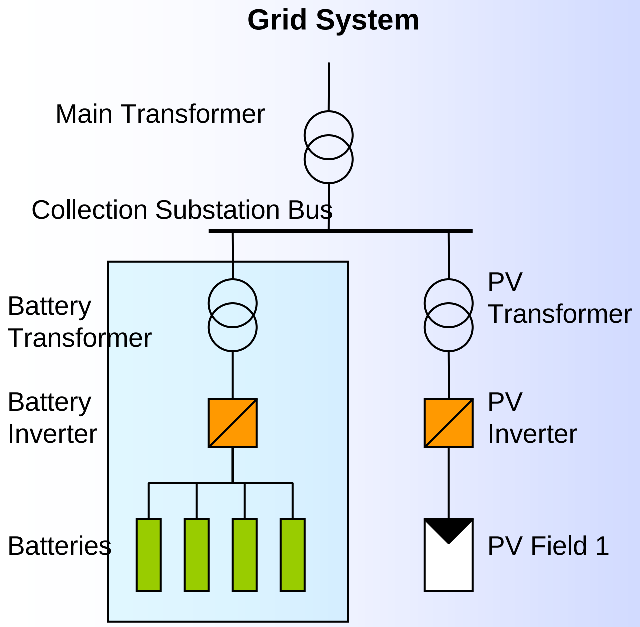
- Energy storage systems have fast response for regulating voltage and frequency
  - Reduce need for additional regulation capacity
- Fast response of battery systems good match with PV generation
- Battery systems when located at the generation plant
  - Limit power output ramp-up / ramp-down
  - Smooth power output
  - Firm up power output
- General applications include:
  - Ancillary Services (Frequency and Voltage regulation)
  - Peak Shaving / Load Leveling
  - Arbitrage

Integration of Battery Storage in PV Plants

- Design Criteria
  - Capital Investment
  - Performance, Reliability & Efficiency
  - O&M Cost
- Two alternatives
  - Centralized configuration (AC connection) and Distributed Configuration (DC connection)

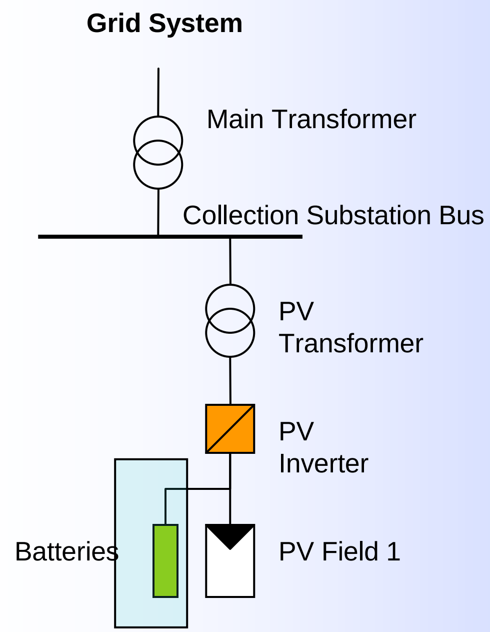
Centralized vs. Distributed Configuration

	Centralized Configuration
Location	at the collection substation
Connection	to the switchyard bus medium voltage AC
Equipment	Dedicated inverters and transformers the same size as the battery, plus breakers. Commercially available and proven



Centralized vs. Distributed Configuration

	Distributed Configuration
Location	at the PV block
Connection	To the PV block inverter, low voltage DC
Equipment	Uses the existing PV block inverter and transformer. Requires a PV inverter that controls battery and PV modules



Battery System

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Battery / Inverter

- Battery
  - Commercial batteries come in standard sizes
    - NAS – 6-7 hours, 1 MW
    - Li-Ion – 15 min, 500 kW
    - Flow batteries – 2-6 hours, 250-500 kW
- Inverter
  - Technology commercially available and operational but not in conjunction with batteries and PV modules

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Design Considerations

Centralized	Distributed
•Dedicated inverters and transformers	•Shares inverter and transformer with PV field •PV inverter needs modifications to handle PV modules and batteries
•Additional connection bay equipment at the collection bus	•Uses existing collection feeder
•Battery size scalable	•Individual battery size limited by the PV inverter. Not all batteries can be used.
•Efficiency – additional electrical losses if charged from the solar field, i.e. two pass through inverters & transformers for grid regulation	•Efficiency – similar losses for any charging strategy •PV inverter better utilized, potential for higher efficiency •More complex battery control coordination, e.g. clouds unequally affect solar field

Financial Considerations

Centralized	Distributed
•Additional equipment, increased Capital Investment •Bigger batteries may reduce Capital Investment differential	•Lower Capital Investment •Modification of PV inverters reduces Capital Investment differential
•Equipment commercially available, tested, and in operation	•Technology available but not applied in this configuration •Testing and commercial operation required to proof reliability
•System efficiency likely to be lower, increasing operational cost, levelized cost	•Efficiency – similar losses for any charging strategy

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Conclusions

- Battery systems are not economically attractive and with current regulations, Renewable Energy is not required to provide grid regulation - storage systems are not required.
- Distributed configuration has the potential for reducing capital investment and operational cost, making the battery system more attractive
- Distributed configuration is technically possible. Some battery and inverter manufacturers have started offering it.
- Operational advantage has to be validated
- Lack of distributed configuration systems in operation, is a risk for investors, which prevents consequently pilot tests and commercialization

Other considerations

- Distributed configuration could also be used in new Type 4 wind turbines. While this improves power output quality, it increases the wind turbine cost.

QUESTIONS?

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