Battery Storage Policy: Considerations for System Operation and Regulation

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Agenda

- Conventional synchronous generators as energy storage Systems
- Traditional power system operation and control
- Impact of low rotational inertia on power system operation
- Implications for power system operation and control
- BESS Virtual Synchronous generators for increased system stability

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Conventional synchronous generators as energy storage Systems

Conventional synchronous generators as ESS

- Key Energy Storage Characteristics:
  - Rotational inertia (storage of kinetic energy)
  - Thermal inertial (storage of thermal energy)
  - Operating philosophies (usage of fuel storage to support grid stability)

Conventional synchronous generators as ESS

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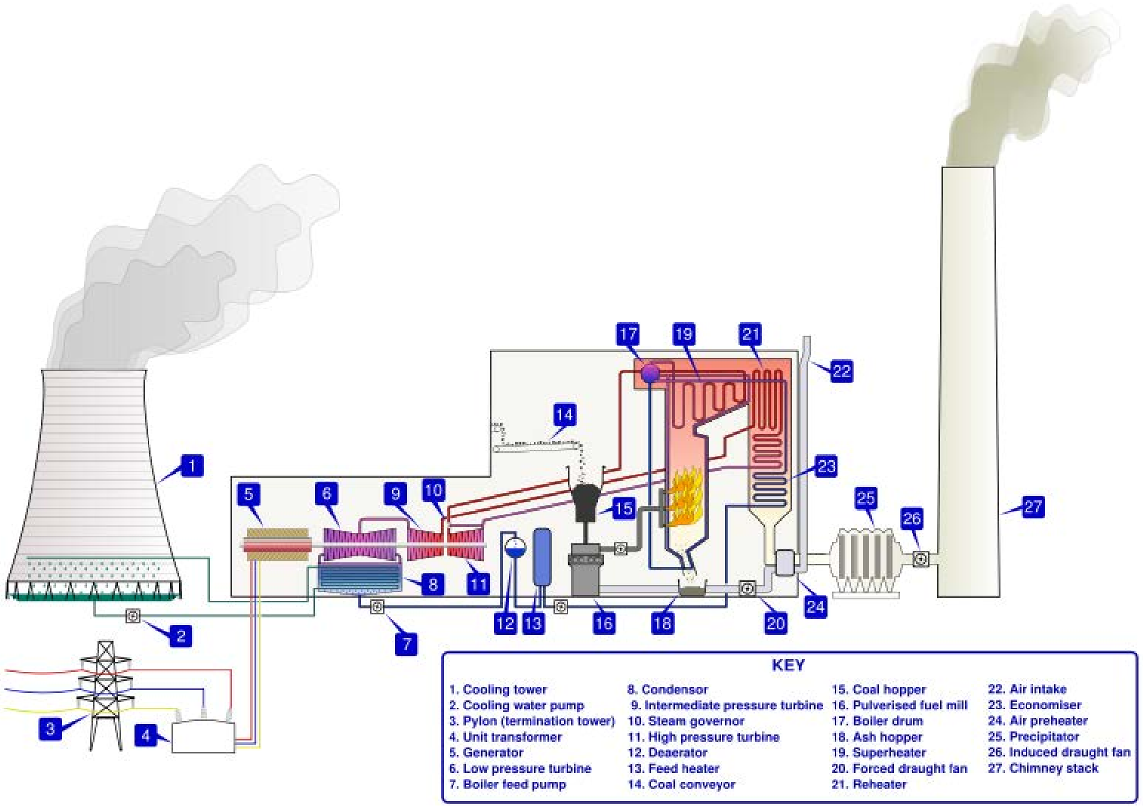
Conventional synchronous generators as ESS



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Traditional power system operation and control

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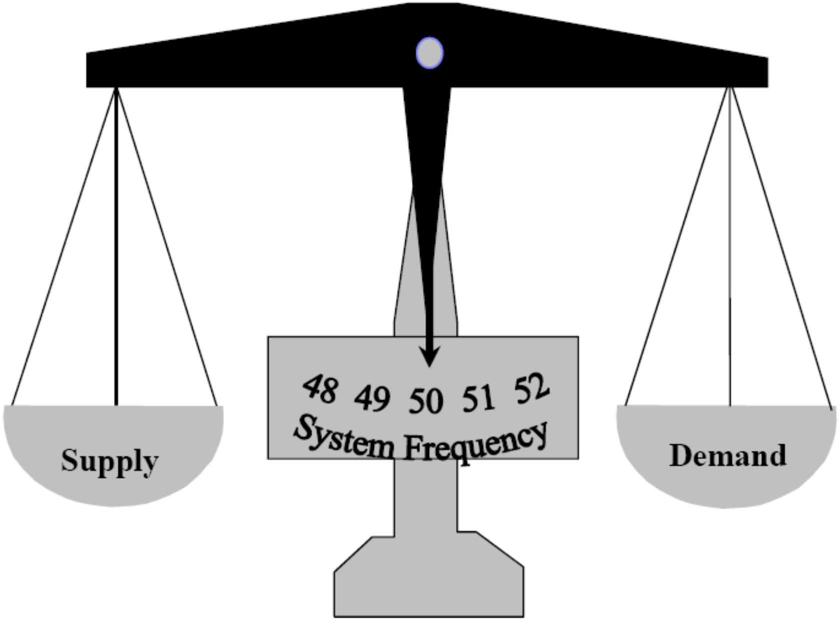
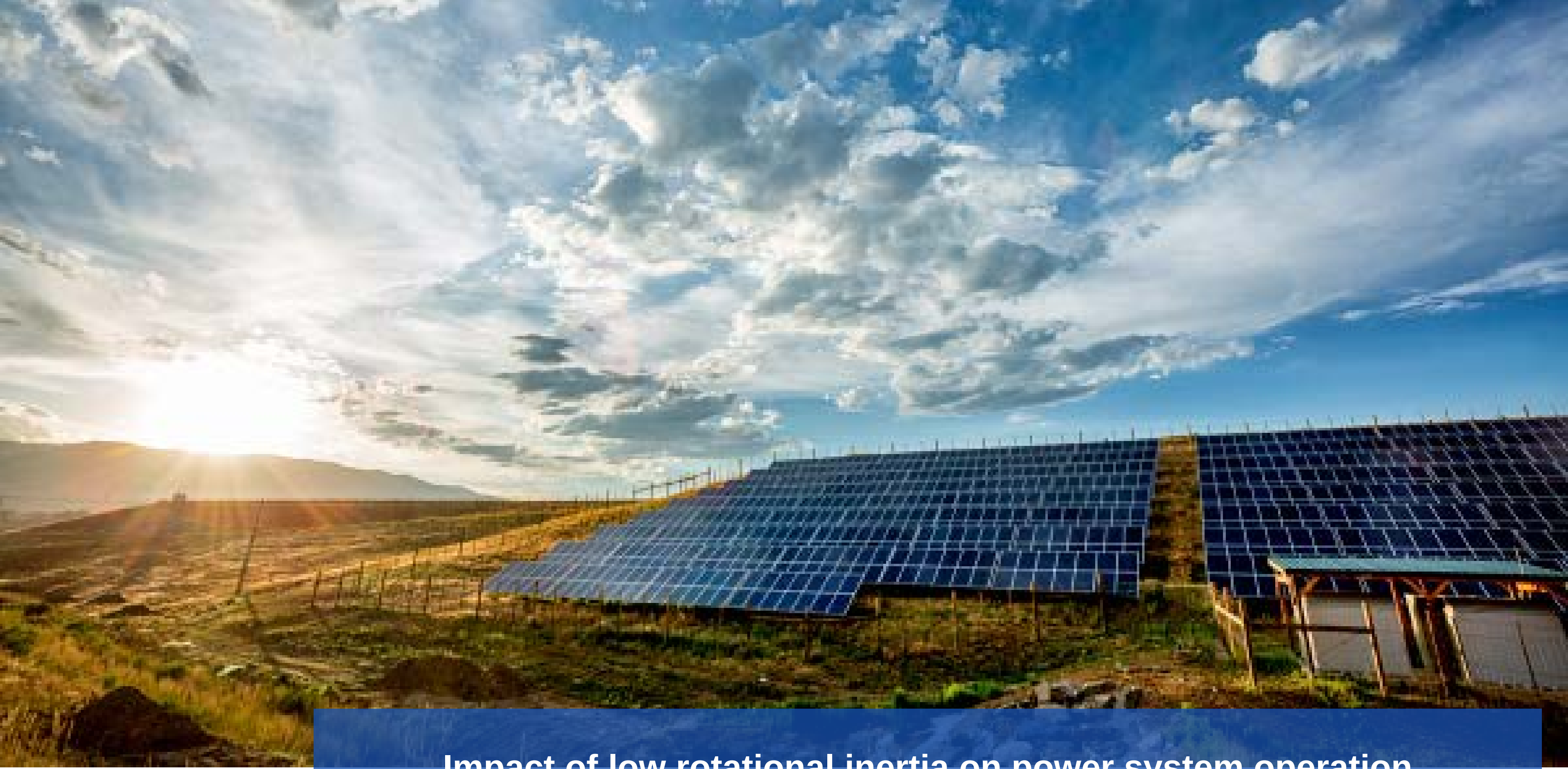
Traditional power system operation and control



Traditional power system operation and control

- Traditionally, power system operation is based on the assumption that electricity generation is fully dispatchable
- Via their stored kinetic energy SGs add rotational inertia, an important property of frequency dynamics and stability.
- The contribution of inertia is an inherent and crucial feature of rotating synchronous generators.
- Rotational inertia minimizes frequency deviations This renders frequency dynamics more benign, and thus increases the available response time to react to fault events such as line losses, power plant outages or large-scale set-point changes of either generation or load units.



Impact of low rotational inertia on power system operation

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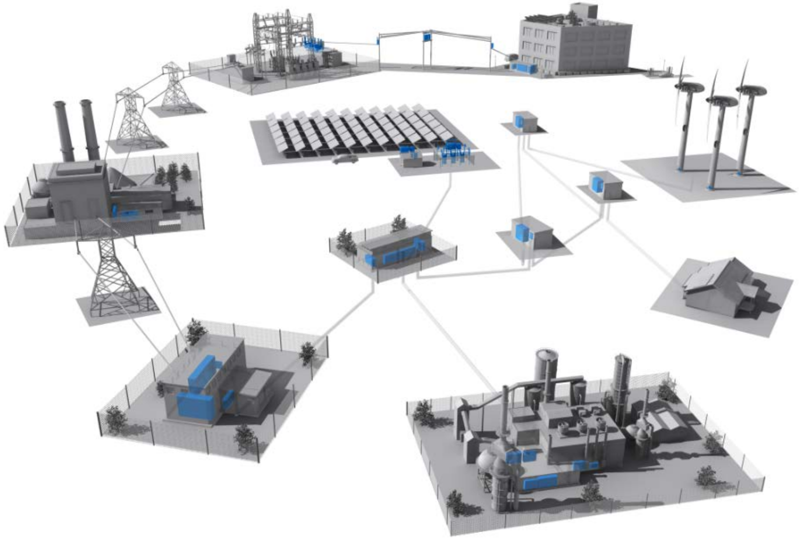
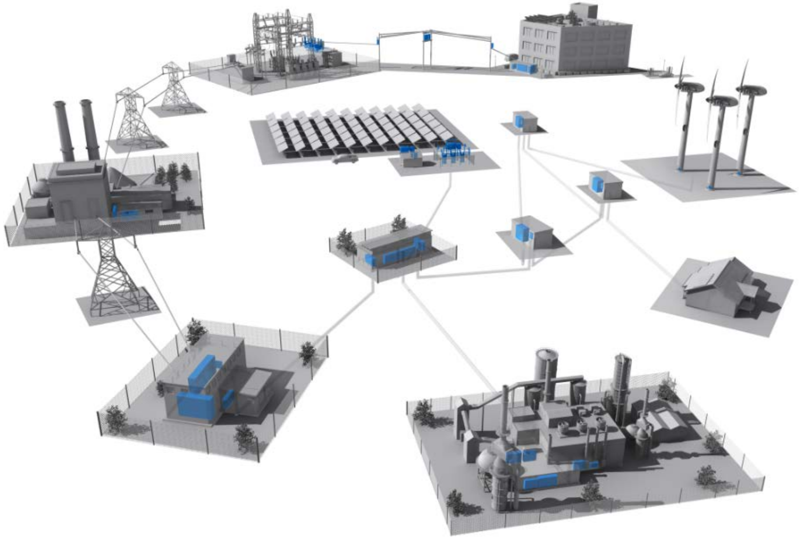


Impact of low rotational inertia on power system operation

- RES units, that do not provide rotational inertia, are displacing conventional generators and their rotating machinery
- Low levels of rotational inertia in a power system, have implications on frequency dynamics which are becoming faster in power systems with low rotational inertia.
- This can lead to situations in which traditional frequency control schemes become too slow to prevent large frequency deviations



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Implications for power system operation and control

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Implications for power system operation and control

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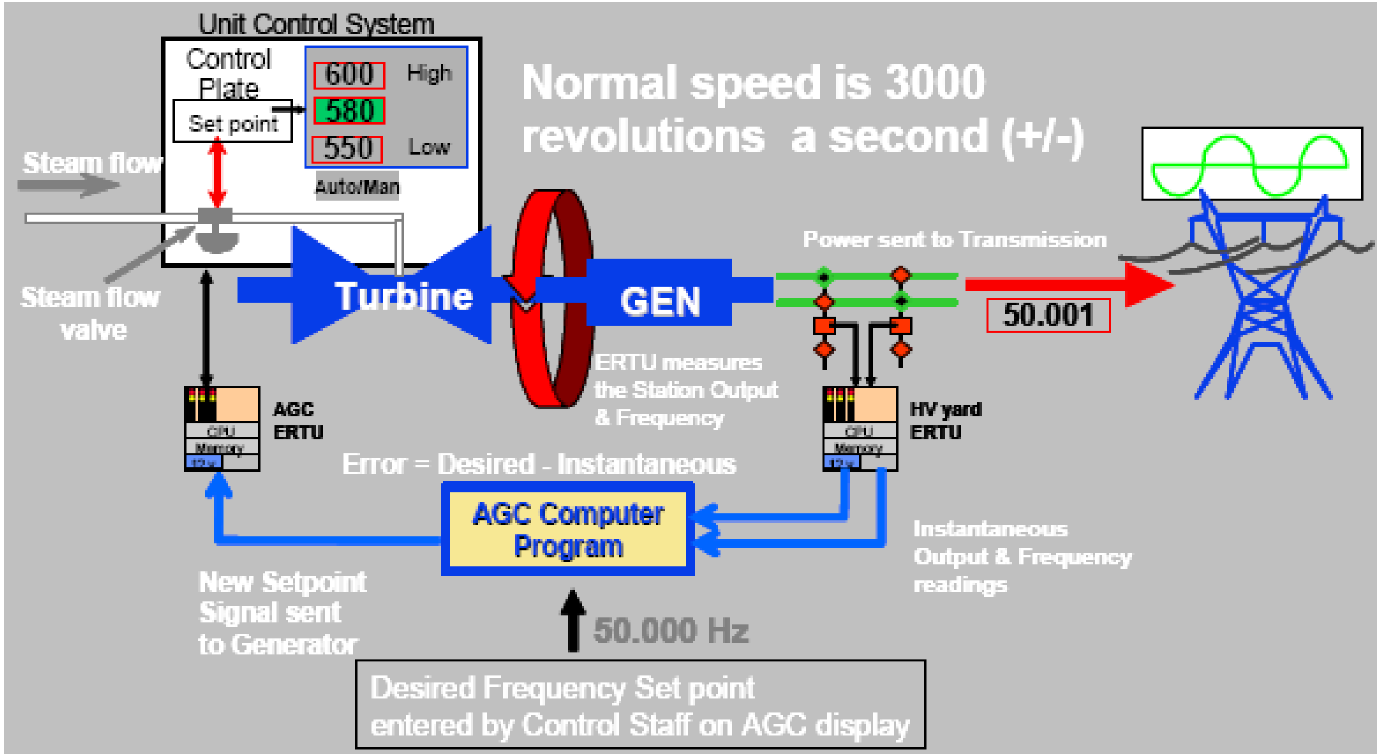
Implications for power system operation and control



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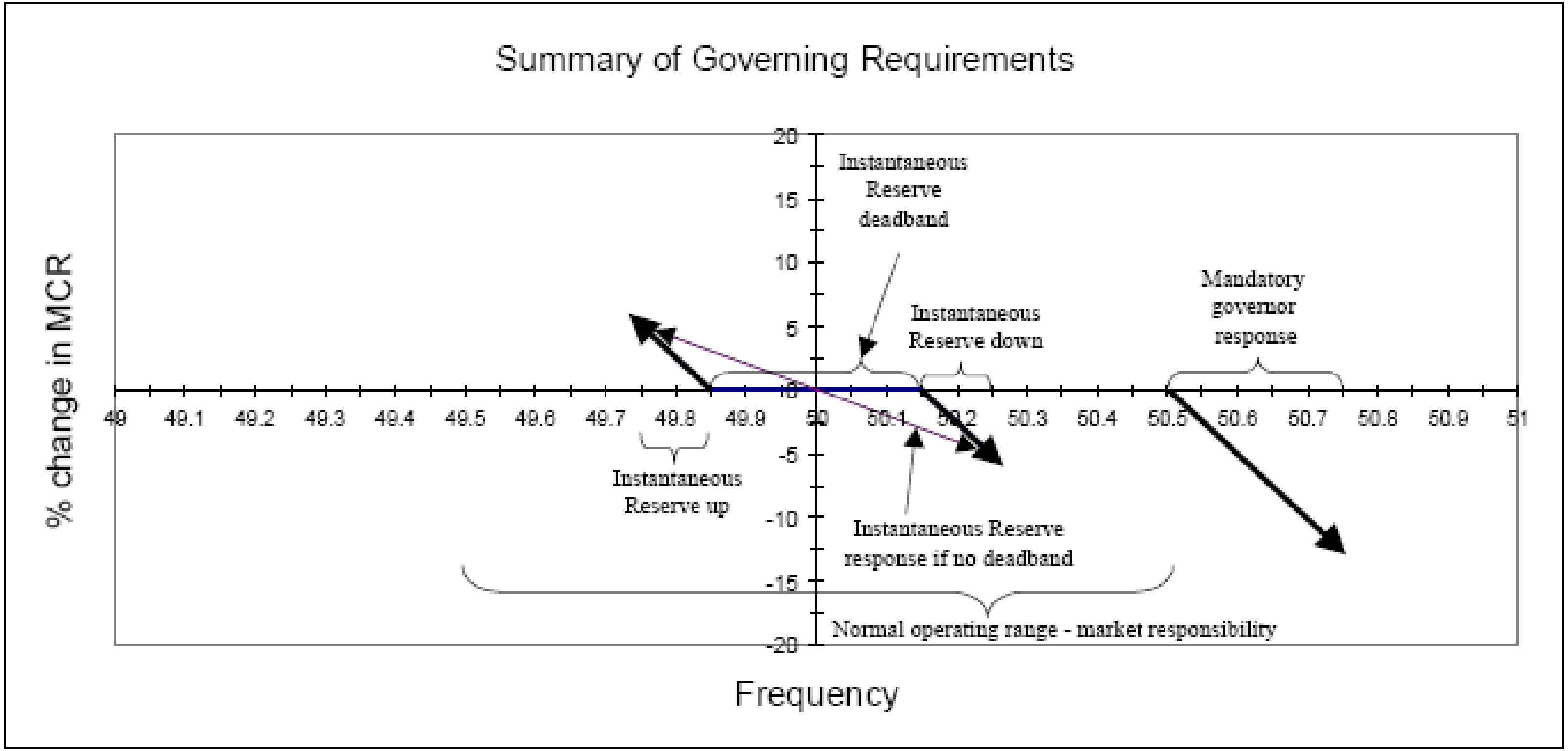
Implications for power system operation and control



Implications for power system operation and control

TOTAL RESERVES

Operating Reserve

Operating Reserve can be activated in 10 minutes and consists of
Supply Side (Spinning and non-Spinning) and Demand Side resources
Operating Reserve is the sum of Regulation, Instantaneous and Ten-minute Reserves

- *Regulation Reserve*

  Start response in 10 seconds and 10 minute full activation – sustained for 1 hour
  Must be on "AGC"
  Contracted on Energy Bid Price cheapest first

- *Instantaneous Reserve*

  10 second full activation - sustained for 10 minutes
  Direct control according to the frequency
  Contracted on Energy Bid Price after Regulation

- *Ten-minute Reserve*

  Frequently used more than once a week, 10 minute activation – sustained for 2hrs
  Can be dispatched via telephone or Direct Control
  Hourly contract based on bid price for capacity, dispatched on energy price

Emergency Reserve

Infrequently used Reserve
Can be dispatched via telephone or Direct Control
Annual Contract and can be used for other emergencies, Dispatched on energy cost

Supplemental reserve

Reserve can be dispatched in 1- 6 hours
Must be available to be dispatched for at least two hours

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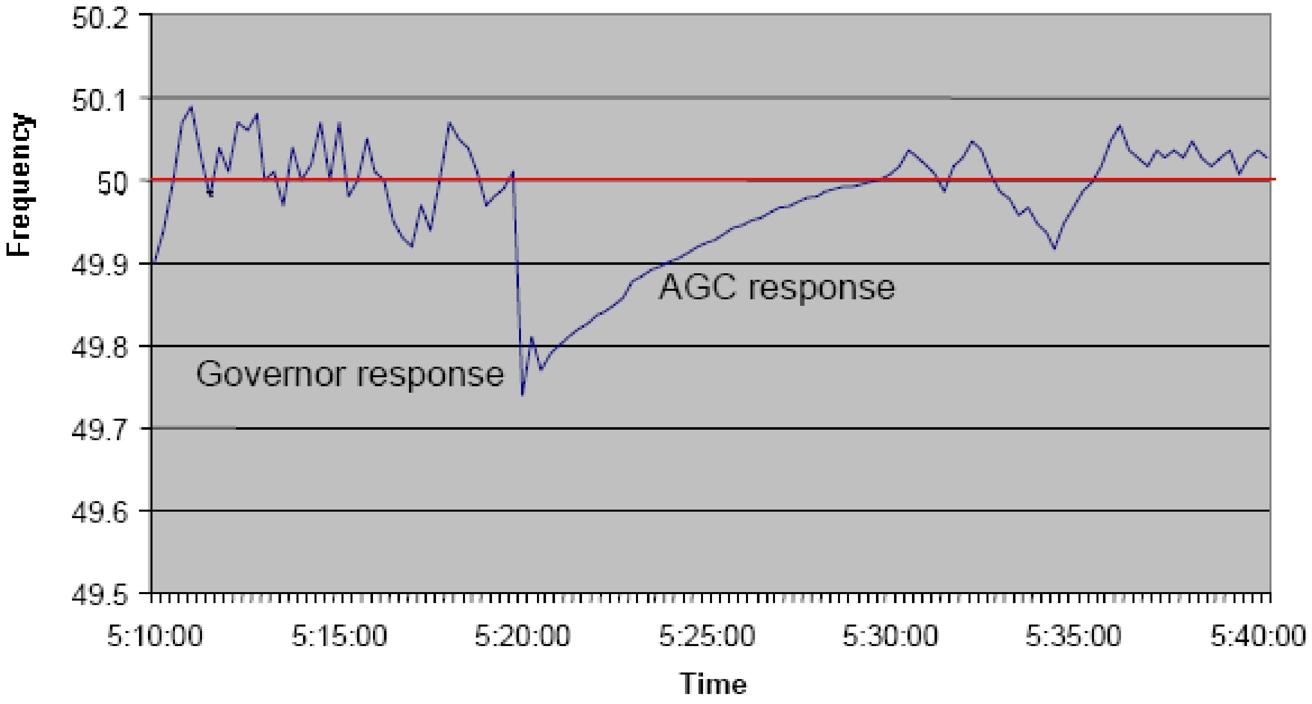
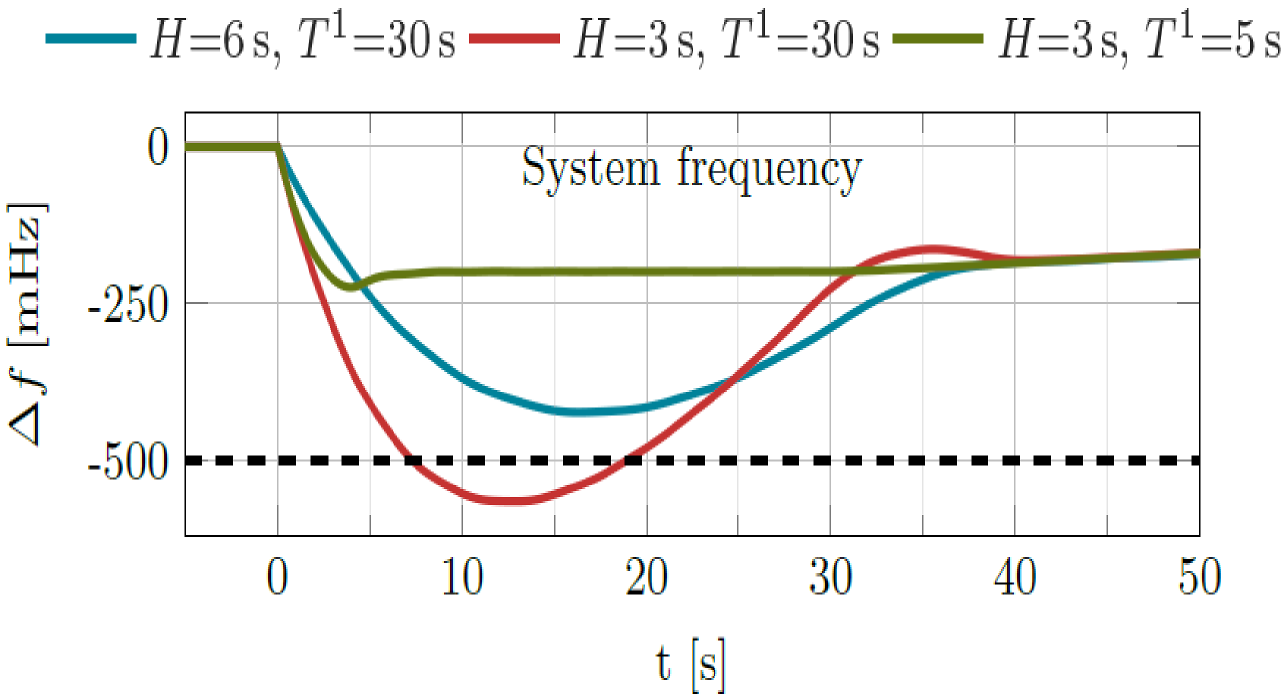
Implications for power system operation and control



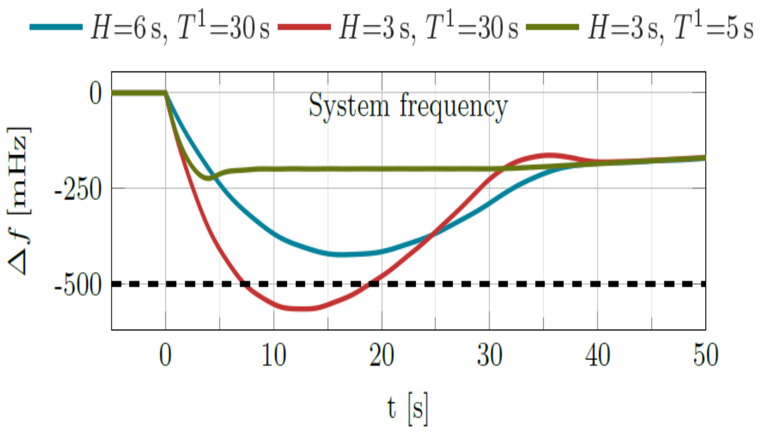
Implications for power system operation and control



Implications for power system operation and control

- Mitigation options for low rotational inertia and faster frequency dynamics are faster primary frequency control and the provision of synthetic rotational inertia, also known as inertia mimicking

- BESS units are, due to their very fast response behavior, especially well-suited for providing either fast frequency (and voltage) control reserves or synthetic rotational inertia for power system operation.



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BESS Virtual Synchronous generators for increased system stability

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BESS Virtual SGs for increased system stability

- A solution towards stability improvement is to provide virtual inertia by virtual synchronous generators (VSGs)

- First term (P_0) denotes the primary power that should be transferred to the inverter. Second term indicates that power will be generated or absorbed by the VSG according to the positive or the negative initial rate of frequency change

- K_I is the inertia emulating characteristic and can be represented by where, P_{g0} is the nominal apparent power of the generator and H shows amount of inertia

$$P_{VSG} = P_0 + K_I \frac{d\Delta\omega}{dt} + K_P \Delta\omega$$

$$K_I = \frac{2HP_{g0}}{\omega_0}$$

Conclusion

- The reason that conventional dispatchable generation works is because they are Power generating units that inherently contain energy storage
- Renewable energy is the future, and necessary for the sustainable power generation. Effective application of energy storage, as virtual synchronous generations, will provide the virtual inertia and storage required to make renewable energy at ever increasing penetration levels possible

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References

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2. H. Bevrani, T. Ise, and Y. Miura, “Virtual synchronous generators: A survey and new perspectives,” *International Journal of Electrical Power & Energy Systems*, vol. 54, pp. 244–254, 2014.

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