Energy Storage System Control for Prevention of Transient Under-Frequency Load Shedding
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Background

What is under-frequency load shedding (UFLS)?
In power systems, generation and demand is continuously balanced using a hierarchy of controllers that maintains frequency close to nominal value (60 Hz in North America).

What is transient UFLS (TUFLS)?
Any unnecessary load disconnection due to temporary frequency decline (NOT due to steady-state frequency deviation) is defined as TUFLS.

What are the causes of TUFLS?
Increased deployments of renewable generations (e.g., solar and wind) that provide less/no inertial and/or frequency support as in traditional synchronous generators.

Motivation

How can we prevent TUFLS?
An energy storage system (ESS) can quickly inject power to arrest transient frequency deviations.

Requirements

- Power injection must quickly be started to make sure that UFLS does not happen during the initial frequency decline
- ESS must have fast response timings, i.e., large ramp rates
- ESS must have sufficient energy and power capacities
- Controller must implement power withdrawal as the ESS cannot sustain power injections for prolonged periods because of its limited energy capacity
- Power withdrawal must be gradual as it could cause a second transient if it is sudden
- Controller must recover the initial stored energy in the ESS
- Local measurements must be utilized to avoid communication delays associated with centralized controllers

Proposed Control Strategy

Controller operates in two stages:
1. Injecting maximum power as soon as a large frequency decline is detected and performing online system identification using extended Kalman filter (EKF)
2. Switching to model predictive controller (MPC) after system recovery is detected to withdraw power and regain lost energy in the ESS

Results

Controller is evaluated using two reliability test systems (RTS): 6-bus RBTS and 32-bus IEEE RTS.

5.1. Controller Performance for RBTS

5.2. Controller Performance for IEEE RTS

Advantages of the Controller

- Capability to withdraw power and recover energy in the ESS while reducing forced disconnection of load
- Utilization of local (non-delayed) measurements in contrast to centralized controller designs
- Ability to adapt to system parameter changes using an online system identification method based on EKF
- Easily implementable in existing power systems, as it uses existing load shedding schemes

Conclusion

Simulations confirm that the controller successfully prevents TUFLS in both 6-bus RBTS and 32-bus IEEE RTS systems.
- The controller successfully recovers energy in the ESS while limiting frequency excursions.

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More Information

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