Optimal Control of Energy Storage for Transient Stability

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Power system stabilizers (PSS) are employed to enhance the transient stability of power systems by providing rapid damping for oscillations of generator rotor angle and speed. Where a PSS is insufficient, energy storage systems (ESS) can provide more damping to the system. Figure 1 shows a single machine infinite bus (SMIB) model with both PSS and ESS implemented. Figure 2 shows the control flow block diagram for this systems.

State feedback is calculated to optimize a performance objective function \( L \). The objective, shown below, is chosen to be a linear combination of the squared frequency and angle disturbances.

\[
L = \frac{1}{2} \int_0^\infty \left[ (\Delta \omega)^2 + (\Delta \theta)^2 + r_1(\Delta V_{ref})^2 + r_2(\Delta P_{ref})^2 \right] dt
\]

\[
u^* = \Delta V_{ref} \Delta P_{ref}^T \quad u^* = -K_s K = R^{-1}B'S\]

In a test system, the rotor speed is assumed to have an initial disturbance of 0.12 Hz. The open-loop system is nearly unstable at 60 Hz with a settling time of 36.37 seconds.

The stability improvements achieved by conventional power system stabilizers (PSS), energy storage system (ESS) damping, and low-frequency high-voltage alternating current (LF-HVac) transmission are stackable. For an example system at 60 Hz, the classical PSS design improves settling time from 63.37 seconds to 7.5 seconds. Employing ESS further reduces the settling time to 1.14 seconds and reducing the operating frequency to 10 Hz improves it to 0.74 seconds.

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