A Comparative Study of Robust Strategies for Single-Area Power Systems

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Abstract:
Load Frequency Control (LFC) is critical for ensuring stable operation of power systems, especially under diverse operating conditions. Within the analyzed single-area power network, the area control error (ACE) has been effectively managed despite uncertainties in system dynamics and the presence of external disturbances. The most recent study on disturbance rejection mechanisms has revealed that Active Disturbance Rejection Control (ADRC) is an effective controller for controlling uncertainty in systems, whether the system is linear or nonlinear. The importance of the ADRC controller resides in its model-free nature, that requires little understanding of the system model. The extended state observer (ESO) facilitates continuous estimation and compensation for disturbances, whether originating within the system or from external environments. However, certain process disturbances, such as time-delay, makes ADRC controller design more difficult. A solution to this problem is to use a Disturbance Observer (DO) which improves system performance. This study presents a comparative analysis of six control strategies: General Active Disturbance Rejection Control (ADRC) Controller with neglected delay, Delayed Input ADRC Controller, Smith Predictor ADRC Controller (ADRC-SP), Disturbance Observer (DO), PID (Proportional plus Integral plus Derivative) Controller, and PI (Proportional plus Integral) Controller, for their effectiveness in LFC of a single-area power system. Controllers are evaluated based on key performance metrics such as settling time, rise time, overshoot, and Integral of Absolute Error (IAE) under three scenarios: step load change, variable wind speed penetration, and $12\ \mathrm{m/s}$ constant wind speed penetration. The results highlight the superior performance of the Disturbance Observer in minimizing settling time, overshoot, and Integral Absolute Error (IAE), making it the most robust and efficient controller among the evaluated strategies.

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