ABSTRACT

SETTINGS-LESS ADAPTIVE PROTECTION IN AC MICROGRIDS: A COMPARATIVE FRAMEWORK BASED ON MODEL-DRIVEN DYNAMIC STATE ESTIMATION

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High penetrations of inverter-interfaced Distributed Energy Resources (DERs) make microgrid fault levels, power-flow directions, and operating points highly variable, eroding the reliability of protection schemes based on static pickup settings. This dissertation develops a setting-less, model-based protection architecture that replaces fixed thresholds with model-consistency evidence generated by dynamic state estimation (DSE) and adjudicated by physics-informed validators, all operated under explicit computational and communication budgets.

The pipeline is modular and estimator-agnostic, supporting square-root sigma-point/ cubature filters (SR-UKF/CKF with adaptive noise covariances ratio Q/R, robust innovations, χ^2/ NEES gating), ensemble/particle methods where non-Gaussian behavior dominates, and two-layer moving-horizon estimation (TL-MHE) for constraint-aware feasibility checks. Validators include Sequential Likelihood Ratio Tests (GLRTs) on whitened innovations, residual-energy concentration, and boundary-flow invariants for internal/external discrimination; decisions are issued through persistence–confirmation logic gated by estimator-health monitors (NIS/NEES coverage, whiteness, positive-definiteness).

A paired, censoring-aware evaluation on an IEEE 14-bus AC microgrid quantifies (i) detection speed, (ii) selectivity/localization, (iii) false-trip behavior on benign events, (iv) robustness to measurement noise and model mismatch, and (v) communication dependency (latency, jitter, loss). Detection times are analyzed via Kaplan–Meier with restricted-mean contrasts; proportions via Wilson intervals and McNemar tests with Holm multiplicity control. To operationalize telemetry constraints, the work introduces a Communication Dependency Index (CDI) that aggregates Communication Load, Latency Sensitivity, and Resilient Coverage Fraction, enabling Pareto analysis and knee-point operating recommendations.