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Editorial: Learning-assisted diagnosis and control of electric distribution network

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Editorial on the Research Topic
Learning-assisted diagnosis and control of electric distribution network

The digital transformation of modern power systems establishes a robust digital foundation for enhanced system observability, operational transparency, and intelligent planning. This paradigm shift centers around harnessing big data resources spanning the entire energy value chain, from generation to end-user consumption (Channamallu et al., 2025). While low-voltage distribution networks face unprecedented challenges from the proliferation of renewable energy integration and electric vehicle penetration, emerging opportunities arise from ubiquitous sensing infrastructure and advanced control architectures (He et al., 2022). Artificial intelligence (AI) has emerged as a pivotal enabler to unlock the latent value of these multidimensional datasets, offering transformative solutions across critical domains including real-time fault diagnostics, adaptive control systems, and holistic grid optimization (Zhang, et al., 2023). The imperative for AI adoption becomes particularly pronounced in modern distribution networks, where escalating topological complexity and dynamic operating conditions necessitate proactive management frameworks and self-healing capabilities (Alam, et al., 2024). Conventional model-driven approaches, reliant on physical mechanism interpretation and static control paradigms, demonstrate inherent limitations in adapting to frequent network reconfigurations characteristic of distribution-level operations (Chen, et al., 2024). Nevertheless, direct implementation of existing AI/ML algorithms remains constrained by stringent power system requirements. Critical barriers including cybersecurity assurance, operational generalizability, model interpretability, out-of-distribution robustness, and fail-safe reliability must be systematically addressed prior to industrial-scale deployment. The demonstrated significance of Learning-assisted Diagnosis and Control of Electric Distribution Network has motivated the creation of this Research Topic to address its technical complexities.

The twelve contributed papers in this Research Topic can be categorized into four groups: Fault Diagnosis and Protection, Prediction and Estimation, Control and

Optimization and Voltage and Resonance Suppression. They can be summarized as follows.

Fault Diagnosis and Protection comprises 5 papers

Wu et al. proposed a fault diagnosis framework for distribution networks by integrating D-S evidence theory with Bayesian networks. The method categorizes relay protection and circuit breaker information into two Bayesian networks to calculate component failure probabilities via backward inference. These probabilities are fused using D-S theory to diagnose faulty components. Forward inference then identifies misoperations or rejections in protection devices. Case study validation demonstrates that the approach achieves enhanced diagnostic accuracy and reliability when addressing protection failures.

Li et al. introduced a fault identification method based on a mixture of von Mises-Fisher (mov-MF) distributions. Voltage phase angles from post-fault steady-state measurements form 3D feature vectors. The model is initialized via spherical K-means and optimized using expectation-maximization (EM) to refine parameters. IEEE 33-node system testing confirms the method's precise classification capability for single-phase (SP), two-phase (TP), and three-phase (3P) faults, demonstrating robust performance across multiple grid scenarios.

Duan developed a Transformer-GAN model for anomaly detection in AI-driven power systems. The architecture combines Transformer self-attention mechanisms with GANs to process complex sequential data, capturing dynamic patterns and unknown anomalies. Multi-dataset evaluation validates the model's 95.18% accuracy and 96.64% AUC with superior recall rates. Its robustness and adaptability highlight its potential for enhancing grid security and IoT integration.

Guo et al. designed the DSC-BiGRU-MAM framework for diagnosing faults in flexible converter valves. Depthwise separable convolution (DSC) extracts local features, while bidirectional GRUs model temporal dependencies. A multi-head attention module dynamically weights critical time intervals and channels, suppressing irrelevant features. Noisy environment testing reveals the model's 95.45% operational accuracy at 17,626 parameters and training time 935 s.

Wang et al. presented a differential protection scheme for grids with distributed generation. Whale optimization-enhanced feature mode decomposition processes zero-sequence current waveforms, while derivative dynamic time warping of the largest fault feature component solves distribution network grounding current differential protection issues. MATLAB simulations validated the method's ability to handle single-phase ground faults, ensuring stable operation under diverse fault conditions.

Estimation and Prediction includes 3 papers. Qian et al. proposed a fuzzy decision-making model for rapid equipment status assessment. Key indices from multi-source data are mapped to equipment scores using fuzzy iteration and XGBoost. The hybrid approach outperformed traditional methods in speed and accuracy, validated through distribution transformer case studies, enabling proactive maintenance.

Fang et al. created the Seasonal-Temporal Correlation Deep Forest (STC-DF) model for offshore wind speed prediction. The model autonomously learns seasonal and temporal patterns without manual feature engineering. Hainan wind farm data analysis demonstrates 40% error index of the corrected wind speed reduction and 15% prediction accuracy enhancement.

Zhang et al. integrated CNN and Kolmogorov-Arnold Networks (KAN) for lithium-ion battery SOH estimation. Multi-feature extraction during constant-voltage charging (e.g., current integrals, temperature trends) feeds into a CNN for feature selection, while KAN models nonlinear degradation. Experiments across charging rates yielded a good results, outperforming conventional methods in handling battery aging nonlinearity.

Control and Optimization consists of 3 papers. Li et al. optimized EV charging station stability using a fractional-order impedance model. A fractional PID controller, tuned via particle swarm optimization, enhanced virtual inertia and suppressed DC voltage oscillations. Experimental results showed 0.025s response time, 5% voltage deviation limits, and rapid inertia stabilization, ensuring grid resilience under high EV penetration.

Li et al. devised a cluster-based voltage control strategy for PV-rich distribution networks. An improved community algorithm divides nodes into reactive/active clusters based on power balance and coupling. PV inverters regulate voltage collaboratively, reducing overvoltage incidents in IEEE 69-node simulations and improving PV integration capacity.

Sun and Liao proposed the MARL-SOM-GNNs model for UAV cooperative grid inspections. Multi-agent reinforcement learning optimizes UAV coordination, self-organizing maps cluster inspection data, and graph neural networks analyze grid topologies. The framework achieved superior inspection accuracy and adaptability to environmental changes, setting benchmarks for autonomous infrastructure monitoring.

Voltage and Resonance Suppression contains 1 paper. Yonghao et al. investigated remanent magnetism's role in suppressing ferromagnetic resonance in 10 kV all-cable grids. A PSCAD model with UMEC-based voltage transformers simulated DC-induced residual magnetization. Results revealed positive magnetization effectively reduces PT inrush currents, while negative values exacerbate resonance. These findings guide grid design to enhance stability and prevent resonance risks.

Significant advancements have been achieved in the Learning-assisted Diagnosis and Control of Electric Distribution Network in recent years. However, these research accomplishments would not have been possible without the scholarly contributions of authors and the critical comments by reviewers. This Research Topic aims to illuminate emerging frontiers within the Learning-assisted Diagnosis and Control of Electric Distribution Network domain while formally recognizing dedicated efforts to address persistent technical challenges in the field.

Author contributions

CZ: Writing – original draft, Writing – review and editing, Conceptualization. AT: Investigation, Writing – original draft. XW: Writing – review and editing, Conceptualization. DG: Writing – review and editing.

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