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Editorial

Situational Awareness for Smart Distribution Systems

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1. Introduction

In recent years, the accelerating climate change and intensifying natural disasters have called for more renewable, resilient, and reliable energy from more distributed sources to more diversified consumers, resulting in a pressing need for advanced situational awareness of modern smart distribution systems. The continuous connection of distributed generation, energy storage, and renewable energy to the grid also enriches the power supply while introducing new consumption patterns and pressures to the power systems.

Modern situation awareness for the smart distribution systems is based on a holistic, panoramic view of the entire operating environment, including the power supplies and the user behaviors, to provide comprehensive perception, comprehension, and prediction for the system. While advanced situational awareness has been widely used in military, transportation, justice, and other fields, it has also become an enabling technology following the digitization and informatization of society.

In this Special Issue, we present ten recent studies on a wide range of topics in the situation awareness for smart distribution systems.

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2. Short Review of Contributions

Situational awareness is essential for the planning and operation of an integrated energy system (IES), which needs to coordinate between different energy sources based on the accurate states of all interconnected systems. In [1], Li et al. proposed a novel situational-awareness-based planning strategy to optimize the system capacity, where a bi-level model optimizes multiple environmental and economic objectives while addressing the system stability requirements. Solved by an improved NGSA-II algorithm and the Cplex solver, their model effectively improves system stability and reduces carbon emission for wind–photovoltaic–thermal power systems.

Microgrids with hydrogen, wind, solar, storage, and other energy sources have become a new norm of IES. In [2], Wang et al. proposed a two-stage IES energy management model for wind–PV–hydrogen–storage microgrids based on receding horizon optimization to tackle the impacts of uncertainties and fluctuations. Their day-ahead optimization in the first stage and intra-day optimization in the second stage have successfully mitigated the uncertainties and maintained the grid stability at low operation costs across the microgrid.

The increasing penetration of renewables such as wind power brings uncertainties with significant challenges to the economic dispatch for IES. To tackle this, [3], Liu et al. proposed a distributed two-stage chance-constrained dispatch model that can optimize the IES operation with robustness against wind uncertainty. Considering practical operation constraints and acceptable risk levels, the new model can be solved efficiently by mixed-integer tractable programming. Its effectiveness is demonstrated on an IEEE electricity–gas–heat test case with reduced operating costs.

The development of IES poses new challenges to traditional demand response (DR) programs in distribution grid energy management and optimization. In [4], Li et al. proposed an integrated DR optimization method based on combined models of responsive electric loads, building thermal dynamics, day-ahead scheduling, and user participation. The final optimal scheduling mechanism can effectively reduce the operation cost of a community while considering users' willingness to participate and the utility's requirement of dispatching, while the robustness is further enhanced based on the conditional value-at-risk (CvaR) theory.

DC series arc faults pose severe challenges to the safety of photovoltaic (PV) systems in a smart distribution grid. In [5], Wang et al. proposed a lightweight convolutional neural network (CNN)-based detector to enable the fast and accurate detection of DC series arc faults on resource-limited embedded sensors in PV systems. As an edge-friendly solution, their computationally efficient model can nonetheless precisely detect most faults in various test conditions on the UL1699B test platform.

While numeric data are the norm of smart distribution system instruction, text data such as event logs and operator reports comprise another crucial information source. In [6], Liu et al. proposed a short-text classifier for secondary distribution equipment based on convolutional neural networks (CNNs). Contextual semantic features are auto-extracted from words to mine the fault information in text descriptions of faults and defects, which demonstrates their effectiveness on the real operation data from a regional power grid.

Non-intrusive load monitoring is a key for informed and flexible energy management in smart distribution systems. In [7], He et al. proposed a new denoising auto-encoder (DAE)-based strategy that can effectively disaggregate the residential load without additional data acquisition. Based on regular active power measurements, their method outperforms traditional hidden Markov model (HMM)-based techniques and accurately monitors household appliance consumption in a non-intrusive manner.

As electric vehicles become the future norm of transportation, their charging demand has also become a focus of short-term load forecast in distribution systems. In [8], Zhang et al. proposed a combined strategy of multi-channel convolutional neural network and temporal convolutional network (MCCNN–TCN) to improve the short-term load forecast of EV-charging demands. By finding temporal characteristics and dependencies in time-series data from urban charging stations and meteorological information, the strategy effectively improved the forecast performance over other state-of-the-art methods.

Thermal load is another important focus of load forecast in distribution systems due to their sensitivity to human preferences and seasonal patterns. In [9], Sun et al. proposed a new load forecast method based on innovative models of thermal comforts and the attention mechanism in long short-term memory (LSTM) networks. Validated on real-world data from Northern China, the new strategy achieved a more accurate forecast of the electric-heating loads to improve the safety and stability of smart distribution systems.

Situational awareness is essential in the high-quality operation and maintenance of smart distribution systems. In [10], Ge et al. provided a brief yet inclusive review of detection, comprehension, and projection technologies to enhance situational awareness in smart distribution systems. The review is expected to provide researchers and utility engineers with insights into technical achievements, barriers, and directions of situational awareness for future smart distribution systems.

3. Conclusions

We sincerely hope the papers included in this Special Issue will inspire future research into situation awareness for smart distribution systems. We strongly believe that there is a need for more work to be carried out, and we hope this issue provides a useful open access platform for the dissemination of new ideas.

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