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EDITED AND REVIEWED BY
Jun Liu,
Xi'an Jiaotong University, China

*CORRESPONDENCE
Libao Shi,
shilb@sz.tsinghua.edu.cn

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Editorial: Exploring cyber-physical interactions in energy and power systems: theory and application

Libao Shi*

Shenzhen International Graduate School, Tsinghua University, Shenzhen, China

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Editorial on the Research Topic
Exploring cyber-physical interactions in energy and power systems: theory and application

As the swift development of information technology and clean energy related technologies, the power grid has evolved into a high-dimensional, complicated, and strongly coupled physical-cyber energy and power system. On the one hand, the modern information techniques provide key technical guarantee for the stability and controllability of the physical power grid, and on the other hand, some potential risks from information networks, such as cyber failure and malicious intrusions and so on, will produce unpredictable risk propagation through the information and physical system interactions, which will bring about disturbance of the physical power grid or even cause power outages. Deeply exploring the interaction behavior and influence mechanism of the physical-cyber coupled energy and power system will be beneficial for identifying potential risks of the system and further enhancing the reliability of the whole system.

The Research Topic aims to study the interactive influence mechanism of the physical-cyber coupled energy and power system, and timely and accurately discover and eliminate the possible risks of the system utilizing the relevant scientific theory and expertise in the professional fields to better achieve the reliable and safe operation of the physical-cyber coupled energy and power system. After undergoing a rigorous peer-review process, total 5 articles have been accepted for publication, which are summarized as follows.

In the article "Cyber-physical cascading and resilience of power comprehensive review," Islam Z. M. et al. provided a comprehensive literature review involving the modeling, analysis, and measures of cascading failure in a cyber-physical power system to help researchers better understand the cutting-edge of cascading failure in the cyber-physical coupled power systems.

In the article "Real-time Volt-Var control of grid forming converters in DER-enriched distribution network," Wagle R. et al. proposed a reactive power control framework to handle the voltage violations in a distribution network through grid forming converters. This framework can adjust the voltage magnitude by scheduling the reactive power through intelligent converters, and the Volt-Var control can be achieved in real time by performing joint physical-cyber simulations based on the Typhoon HIL 604 and OpenDSS.

In the article "Cyber-attack research for integrated energy systems by the correlated matrix based object-oriented modeling method," Tong H. et al. presented an object-oriented

model based on a correlated matrix to model the cyber attack, in which the relation between the victim and attacker was directly constructed, the packets and the attack path can be followed, and the states of links and buses can be illustrated pertinent to a cyber attack. The following two aspects, namely, using the object-oriented method to represent the procedure and approach of the cyber attack, and establishing a correlated matrix for the network topology, attack procedure and attack path were adopted to build the final cyber attack model.

In the article "An intelligent analysis method of security and stability control strategy based on the knowledge graph," Wen B. et al. proposed an intelligent analysis approach of power grid stability and security control scheme in accordance with the knowledge graph. Combined with the knowledge graph theory, a clear-structured knowledge network was designed, a 6-element ontology model of the power grid stability and security scheme was constructed, and the human-machine interactive behavior including graph-based decision-making, scheme reasoning and smart search were realized.

In the article "A dynamic game model for assessing risk of coordinated physical-cyber attacks in an AC/DC hybrid transmission system," Liu X. et al. and Shi L. et al. proposed a three-level cyber-physical defense and attack risk evaluation scheme in accordance with game theory to find out the inherent risks of the whole system. Specially, a false data injection attack model was established based on AC state estimation to perform more stealthy cyber attacks, and the attack success probability with the false data injection behavior pertinent to the target substations was quantified elaborately. The proposed dynamic game risk evaluation scheme was transformed into a bi-level mathematical optimization problem for solution.

The current research work still focuses on the theoretical significance, and the behavior characteristics of some specific components and the complicated dynamic process of the system are not taken into account. In particular, in the near future, more clean energy systems with strong uncertainty and a large amount of high-power electronic equipment will be integrated into the physical-cyber coupled energy and power system, whether on the power supply side, the grid side and the user side, making the interactions between information systems and physical systems extremely complex and changeable. In addition to the research on the theory and application of physical power system respectively, how to effectively construct an integrated model considering the interactions between actual power flow and information flow becomes an important problem to be solved urgently to explore the interaction behavior of the physical-cyber coupled energy and power system in the future. With the massive power measurement data and information communication data pouring into the power grid, the traditional model-driven method has become inadequate, and the artificial intelligence technology with data-driven as the core provides an effective way to conduct in-depth and systematic study on the interaction behavior of the physical-cyber coupled energy and power system. Specially, if the model-driven method and the data-driven method can be fused, it will be more efficient to perform more comprehensive and accurate analysis for the physical-cyber coupled energy and power system.

Author contributions

LS is responsible to summarize articles 1–5, and is also responsible to write and check the whole paper.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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