Guest Editorial Special Issue on Recent Advances for Intelligence in Power and Energy Systems

I. Introduction

POWER and energy systems are lifeline infrastructures to civilization. Their stable operation and security of supply are essential for the daily life of the people. Typically, they are characterized by a central generation infrastructure using large-scale power plants. The electricity is transported via long-distance transmission lines on high-voltage levels and distributed via distribution grids to customers on medium and low-voltage levels.

However, we are facing ongoing advances in renewables and energy storage systems, along with innovative information, communication and control technologies, computational intelligence, as well as power electronics. Thus, there are opportunities and challenges emerging in the design, planning, and operation of these assets. Nowadays, there is a clear trend to a more distributed system architecture with more local energy consumption.

II. Aims of This Special Issue

The main purpose of this Special Issue is to discuss recent advances for intelligence in power and energy systems. The IEEE Systems, Man, and Cybernetics (SMC) Society has a lot of activities that provide potential solutions for more intelligence in power and energy systems. Therefore, this guest editorial is technically supported by the SMC Technical Committees (TC) related to Intelligent Power and Energy Systems, Infrastructure Systems and Services, as well as to Intelligent Industrial Systems addressing topics in the domain of system sciences and engineering as well as in cybernetics, which are all of relevance.

In a strict peer-review process supported by reputed international domain experts from power and energy systems and computational intelligence, finally, 19 excellent articles have been selected by the editorial team for publication in this Special Issue of the IEEE Transactions on Systems, Man, and Cybernetics: Systems. The wide range of challenging and interesting topics addressed can be attributed to four different categories related to 1) power system and microgrid optimization; 2) power and energy systems control; 3) energy systems resilience and diagnostics; and 4) distributed generation and power conversion control. A brief overview of the assignment of the articles to the aforementioned categories and their main topic is shown in Table I.

TABLE I
Overview of Topics and Articles of the Special Section

Category Topic	*Article Topic*
Power system and microgrid optimization	1) Distributed gradient-based algorithm for economic dispatch 2) Multi-objective evolutionary approach for economic dispatch 3) Finite-time distributed optimization for economic dispatch 4) Probabilistic optimal operation approach for hybrid energy systems 5) Power compensation in microgrids via distributed consensus algorithm 6) Multi-agent security control and economic dispatch in microgrids
Power and energy systems control	1) Load frequency control via event-triggered communication 2) Optimal load frequency control via distributed economic MPC 3) Networked power systems fuzzy control 4) Distributed optimal control of energy hubs
Energy systems resilience and diagnostics	1) Resilience indices for cyber-physical power system 2) Event-detection method for power systems 3) Consensus decision-making for microgrids
Distributed generators, electric machines & power conversion control	1) Fuzzy control of DFIG wind turbine 2) Fuzzy-based approach for wind energy conversion systems 3) Event-triggered fuzzy-based concept of electric machines 4) Fuzzy-based robust control of electric machines 5) Sliding mode control for power converters 6) Stability droop coefficient region identification for inverter

In the following, the main content and contributions of these articles are briefly summarized in order to give the readers of this Special Issue guidance through its content.

A. Power System and Microgrid Optimization

The optimization of large-scale power systems but also of microgrids is addressed by six different articles in this category. The first article, written by Guo *et al.* [item 1) in the Appendix], introduces a distributed gradient-based algorithm for the optimization of large-scale power systems under constrained optimization of economic dispatch applications. The following article by Ji *et al.* [item 2) in the Appendix] applies a multiobjective evolutionary optimization concept also for the economic dispatch of power systems. Comparable to the aforementioned works, the following article by Mao *et al.* [item 3) in the Appendix] also covers the

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economic dispatch in a smart grid by using a finite-time distributed optimization algorithm. In contrast to the previous papers, the work from Zhang *et al.* [item 4) in the Appendix] introduces a probabilistic-based optimal operation approach for hybrid energy systems.

The next two articles in this editorial are focusing on the optimization of small-scale systems, i.e., microgrids. Sun *et al.* [item 5) in the Appendix] introduced a power compensation approach for the minimization of network losses by using a distributed consensus concept-based approach whereas Zhang *et al.* [item 6) in the Appendix] are focusing on a joint optimization of economic dispatch and security control parameters.

B. Power and Energy Systems Control

The next category of four articles covers control-related topics in power and energy systems. The first article by Sun *et al.* [item 7) in the Appendix] proposes a load frequency control approach under event-triggered communication whereas Jia *et al.* [item 8) in the Appendix] are addressing the same topics but using distributed economic model-predictive control for an optimal solution. The following work by Shanmugam and Joo [item 9) in the Appendix] deals with the stability and stabilization of networked power systems using fuzzy control. Finally, Qu *et al.* [item 10) in the Appendix] proposed a distributed optimal control of energy hubs for microintegrated energy systems.

C. Energy Systems Resilience and Diagnostics

Resiliency and diagnostics aspects are covered by the next three works of this Special Issue. There, Talukder *et al.* [item 11) in the Appendix] provided a very interesting approach for resilience indices for cyber-physical power systems. A hierarchical event-detection method for power systems is presented in the following article by Ma *et al.* [item 12) in the Appendix]. Finally, Hu *et al.* [item 13) in the Appendix] proposed a decentralized consensus decision-making approach which is applied to multimicrogrids.

D. Distributed Generation, Electric Machines, and Power Conversion Control

The last category of articles is addressing the control of distributed generators and electric machines. Turning to these areas, Sharmila *et al.* [item 14) in the Appendix] investigated the stabilization of fault-tolerant control for doubly fed induction generators with stochastic actuator faults using Takagi–Sugeno fuzzy technique. Subramaniam and Joo [item 15) in the Appendix] studied the fuzzy integral sliding-mode control for permanent magnet synchronous generators.

Mani *et al.* [item 16) in the Appendix] considered an observer-based event-triggered fuzzy integral sliding-mode control for Takagi–Sugeno fuzzy systems. Vadivel and Joo [item 17) in the Appendix] examined the issue of reliable robust fuzzy control with permanent magnet synchronous motor and stochastic actuator faults.

Furthermore, Wang *et al.* [item 18) in the Appendix] proposed a dynamic sliding-mode control approach to the robust voltage regulation of dc–dc boost converters by using interval type-2 fuzzy neural networks. Finally, Wang *et al.* [item 19) in the Appendix] analyzed an impedance-based concept to assess the droop coefficients stability region in the power system with numerous distributed generators.

III. Summary and Conclusion

There are a lot of challenges that need to be solved before turning a passively operated power system and its connected components into an intelligent one. This guest editorial provides an overview of recent advances related to optimization, advance control, resilience, and diagnostic from an SMC point of view.

Anyhow, the readers of this Special Issue have to be aware that only a limited part of ongoing recent research activities related to intelligence in power and energy systems can be covered by the above-mentioned articles. The editorial team hopes that this Special Issue will stimulate and contribute to further ongoing discussions and interesting research work in the above-mentioned energy-related fields.

Finally, the editorial team wishes the readers of this Special Issue an enjoyable reading of all included articles.

Acknowledgment

The editorial team wants to thank all contributing authors and the reviewers for their contributions and their constructive comments to this Guest Editorial. We want to express our gratitude to the Editorial Board of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS for their great assistance and patience as well as for accepting this Special Issue; special thanks go to the Editor-in-Chief Prof. Robert Kozma for his outstanding support during all phases leading to the actual publication.

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APPENDIX
RELATED WORK

1) F. Guo, G. Li, C. Wen, L. Wang, and Z. Meng, "An accelerated distributed gradient-based algorithm for constrained optimization with application to economic dispatch in a large-scale power system," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Sep. 5, 2019, doi: 10.1109/TSMC.2019.2936829.
2) J.-Y. Ji, W.-J. Yu, J. Zhong, and J. Zhang, "Density-enhanced multiobjective evolutionary approach for power economic dispatch problems," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Nov. 28, 2019, doi: 10.1109/TSMC.2019.2953336.
3) S. Mao *et al.*, "A finite-time distributed optimization algorithm for economic dispatch in smart grids," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Aug. 19, 2019, doi: 10.1109/TSMC.2019.2931846.
4) H. Zhang, D. Yue, W. Yue, K. Li, and M. Yin, "MOEA/D-based probabilistic PBI approach for risk-based optimal operation of hybrid energy system with intermittent power uncertainty," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Aug. 26, 2019, doi: 10.1109/TSMC.2019.2931636.
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6) Z. Zhang, D. Yue, C. Dou, and H. Zhang, "Multiagent system-based integrated design of security control and economic dispatch for interconnected microgrid systems," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Jul. 22, 2020, doi: 10.1109/TSMC.2020.2997794.
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8) Y. Jia, K. Meng, K. Wu, C. Sun, and Z. Y. Dong, "Optimal load frequency control for networked power systems based on distributed economic MPC," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Oct. 27, 2020, doi: 10.1109/TSMC.2020.3019444.
9) L. Shanmugam and Y. H. Joo, "Stability and stabilization for T-S fuzzy large-scale interconnected power system with wind farm via sampled-data control," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Apr. 30, 2020, doi: 10.1109/TSMC.2020.2965577.
10) M. Qu, T. Ding, W. Jia, S. Zhu, Y. Yang, and F. Blaabjerg, "Distributed optimal control of energy hubs for micro-integrated energy systems," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Aug. 12, 2020, doi: 10.1109/TSMC.2020.3012113.
11) S. Talukder, M. Ibrahim, and R. Kumar, "Resilience indices for power/cyberphysical systems," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Sep. 16, 2020, doi: 10.1109/TSMC.2020.3018706.
12) D. Ma, X. Hu, H. Zhang, Q. Sun, and X. Xie, "A hierarchical event detection method based on spectral theory of multidimensional matrix for power system," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Aug. 9, 2019, doi: 10.1109/TSMC.2019.2931316.
13) B. Hu, C. Zhou, Y.-C. Tian, X. Hu, and X. Junping, "Decentralized consensus decision-making for cybersecurity protection in multimicrogrid systems," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Sep. 17, 2020, doi: 10.1109/TSMC.2020.3019272.
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19) R. Wang, Q. Sun, W. Hu, J. Xiao, H. Zhang, and P. Wang, "Stability-oriented droop coefficients region identification for inverters within weak grid: An impedance-based approach," *IEEE Trans. Syst., Man, Cybern., Syst.*, early access, Nov. 17, 2020, doi: 10.1109/TSMC.2020.3034243.

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