Guest Editorial: Applications of Predictive Control in Microgrids

MICROGRIDS have emerged as a promising solution to accommodate the integration of renewable energy resources. However, there are still many technical challenges related to both the constitutive power electronics circuits and the overall energy management that need to be addressed. For example, the fluctuating outputs from renewable energy resources and variable power demand have posed problems such as voltage/frequency fluctuations. So far, conventional control methods such as cascaded linear control lack sufficient control flexibility and intelligence to handle these issues, resulting in stability problems and power-quality issues. On the other hand, predictive control has been very successful in power electronic converters and complex systems. Due to its fast transient response and flexibility in considering different constraints, predictive control shows huge potential in microgrid applications. This "Special Section on Applications of Predictive Control in Microgrids" of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS presents recent advances of predictive control techniques in distributed generation and microgrids.

As the electronic interface between the renewable energy sources and loads, the power converters play an important role in microgrids. In item 1) of the Appendix, a moving discretized control set model predictive control is proposed for dual-active-bridge (DAB) converters for both load current regulation and dc-bus voltage stabilization in dc microgrids. In the predictive controller, the output dc voltage and the current of the DAB are predicted by using an adaptive step to determine the phase shift duty. The advantages of this method are fast stabilization and load regulation while the system impedance information is not needed.

As to ac microgrids, inverters also face many challenges such as reliability, resilience, and power quality issues. In particular, grid fault has attracted much attention, and the proper operation of inverters under grid fault conditions has become increasingly significant. In item 2) of the Appendix, a voltage support scheme is developed to regulate the point of common coupling (PCC) voltage within the stipulated limit considering the impact of the zero-sequence voltage and resistive–inductive microgrid impedance. In this method, the requirement of zero-sequence current to confine the PCC voltage within limits is first determined. Then, a model predictive current control approach is applied to generate the actual currents for voltage support.

In item 3) of the Appendix, a finite control set model predictive power control for grid-tied ac–dc power converters is implemented to attenuate dc-voltage ripples under unbalanced grid voltage conditions. A closed-loop virtual flux estimator is designed to achieve grid voltage sensorless control, while an adaptive method is adopted for online frequency estimation considering the grid frequency variation.

Another concern is that high common-mode voltages generated by partial switching states will result in common-mode current, overload bearing current, as well as leakage current in distributed generation units like PV systems in microgrids. In item 4) of the Appendix, a double vector model predictive control strategy is proposed for three-level inverters to reduce common-mode voltage and current ripples simultaneously. Specifically, the candidate vectors are reclassified and regrouped from partial basic vectors to restrict common-mode voltage magnitude within one-sixth of dc-link voltage. In addition, this method is able to reduce the computational burden in the controller, while the weighting factor in the cost function is avoided.

In item 5) of the Appendix, a predictive model technique combined control is developed for a permanent magnet synchronous generator (PMSG), based on a stand-alone energy system to supply distributed loads at fixed voltage and frequency. The combined control can maintain both the machine-side and load-side variables at their desired values throughout different operation conditions.

At the system level control of microgrids, the main objectives are to coordinate the power flow among distributed generation units to maximize the overall operational benefits. In this context, the distribution power loss of islanded ac microgrids with electric springs is investigated in item 6) of the Appendix. A predictive controller is then developed to calculate and feed the optimal bus voltage reference to each electric spring. This is to mitigate the overall distribution power loss within the microgrid. In item 7) of the Appendix, a model predictive control energy-management strategy is proposed to distribute power flows in a hybrid power system with fuel cell and battery as energy sources and a waste heat recovery system. By considering fuel consumption, battery state-of-charge (SOC), power slope as well as temperature, the objective function is formulated to optimally meet the demand of load power balancing and to protect the proton exchange membrane from lifetime degradation.

With the recent advances discussed above, the guest editors hope that this Special Section can further promote the research in microgrids and motivate the generation of new technologies to address the current challenges.

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APPENDIX
RELATED WORK

1) L. Chen *et al*, "Predictive control based dc microgrid stabilization with the dual active bridge converter," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 8944–8956, Oct. 2020.
2) S. R. Mohapatra and V. Agarwal, "An advanced voltage support scheme considering the impact of zero sequence voltage under microgrid faults using model predictive control," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 8957–8968, Oct. 2020.
3) H. Yang, Y. Zhang, and J. Liu, "Frequency-adaptive virtual flux estimator-based predictive power control with suppression of dc voltage ripples under unbalanced network," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 8969–8979, Oct. 2020.
4) Chen, T. Liu, C. Qin, J. Chen, and X. Li, "Double vector model predictive control to reduce common-mode voltage without weighting factor for three-level inverters," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 8980–8990, Oct. 2020.
5) R. Mishra and T. Saha, "Performance analysis of model predictive technique based combined control for PMSG based distributed generation unit," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 8991–9000, Oct. 2020.
6) Y. Yang, Y. Qin, S. C. Tan, and S. Y. Hui, "Reducing distribution power loss of islanded ac microgrids using distributed electric springs with predictive control," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 9001–9011, Oct. 2020.
7) Y. X. Wang, H. He, S, Quan, and F. Sun, "Model predictive control with lifetime constraints based energy management strategy for proton exchange membrane fuel cell hybrid power systems," *IEEE Trans. Ind. Electron.*, vol. 67, no. 10, pp. 9012–9023, Oct. 2020.

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