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Editorial

The global economy will be greatly shaped by the transformed energy landscape. The revolutionary progress in the energy sector will eventually impact the way products are manufactured and how ~~the~~ services are provided. A society can only be sustainable if the whole energy chain from top to tail is sustainable. As an enabling technology, control engineering plays an important role in the global effort to achieve 100% clean and renewable transition for all sectors. The themed issues on 'Control Engineering in Shaping a Low Energy Future' offer a venue to disseminate the latest progresses in the applications of novel measurement, modelling, control and optimization technologies for decarbonizing the whole energy chain.

This themed issue comprises 12 papers, covering a broad range of topics, from renewable generation, microgrid, and networked energy systems, to power system cyber security and energy policy.

Wind power is one of the most important and widely available renewable sources that has seen massive investments and rapid development worldwide. Doubly-fed induction generator based wind turbines have been widely used across different wind farms onshore and offshore. To extract the maximal power in the presence of varying wind speeds while satisfying desirable fault ride-through capability still presents a challenge. Huang et al proposed to use a novel Swarm Moth-flame algorithm to optimise the controller parameters of doubly-fed induction generators to achieve maximum power point tracking with enhanced fault ride-though capability. On the other hand, actuator and sensor faults occurring at wind turbines present a significant operational challenge in the presence of harsh environment, and simultaneous reconstruction of various actuator and sensor faults is not an easy task. Rohnavada et al demonstrated that this can be achievable through a sliding mode observer with a modified switch term to reconstruct both the wind turbine hydraulic pitch actuator faults as well as sensor faults. Noticing that unlike conventional thermal power generators, the power output fluctuation is an inherent issue for renewable generators such as wind turbines due to the intermittence and stochastic nature of the renewable sources, which imposes a significant challenge to the power system operation and control, Dai et al investigated the combination of wind turbines with energy storage systems to supply desired power level to the grid, while absorbing excessive renewable generations which are otherwise dumped. The change of operating point of wind turbines during battery charging/discharging causes stability issues of the control, they proposed to formulate the problem as a switched linear system with multiple equilibriums, based on which the controller is designed to guarantee the stability.

Harvesting the waste energy from the abundance of low grade energy resources has a significant impact on improving the overall energy efficiency of both thermal power generators and many energy intensive end users. The organic Rankine cycle systems, which can recover low grade thermal energy have attracted substantial interests in the recent years. Control of the organic Rankine cycle systems proves to be a very important yet challenging issue due to the wide range of operation conditions, and Zhang et al presents a comprehensive review of the overall control strategies for the system operating at both following the connected load mode and following thermal energy mode, which provides a reference point for future researchers in this area.

The mass roll-out of distributed renewable generators, energy storage systems and energy harvesting facilities makes it possible to connect these local power and energy supplies to meet local demands. Microgrids, which serve the purpose of supplying reliable power and energy to local areas are thus becoming one of the hot topics. To optimise the energy dispatch while reducing the cost is one of the primary objectives for the microgrid operation, yet the uncertainties in both the generation side and the end user side make this a rather complicated issue. Zhou et al proposed to use an improved model predictive control scheme with feedback adjustment to control a micro gas turbine, the only controllable generator in the microgrid under study to achieve the purpose of optimal energy dispatch while reducing the cost. On the other hand, voltage control of microgrids is a primary concern in proving reliable power to the end users, however the control quality largely depends on the way these distributed generators communicate, and intensive information exchanges over the communication channels with limited bandwidth may cause network congestions, leading to deteriorated control performance even faults. Shi et al propose to use a distributed event-triggered mechanism to provide secondary voltage control for droop-controlled microgrids with multiple distributed generators, which significantly reduced the information transmitted over the grid and enhanced the control performance.

Power systems from different regions and areas are often interconnected via tie-lines to build a stronger and more flexible grid. Yet, the disturbances present in the power system frequency in individual areas and in the tie-line power interchange are the concerns for stable and economic operation of interconnected power networks. Huang et al investigated the load frequency control problem which regulates the active power output of generators in different power systems to maintain both the frequency in each system and the power flow interchange within the prescribed ranges. This is achieved through the development of a linear active disturbance rejection controller whose parameters are designed using a gravitational search algorithm.

As the energy and power network is becoming exponentially complex due to the landscape changes in the whole energy chain from top to the end, a vast number of facilities and equipment are connected to form cyber physical systems. Cyber security is thus becoming such an important issue that it cannot be overlooked. State estimation is an important step to identify any potential sparse attacks on the cyber physical systems. Zhang et al formulated the state estimation problem as an optimization problem with a unique solution based on which an adaptive estimation method for sparse attacks is proposed. They claim that the proposed method is able to adaptively adjust the step size based on the dynamic estimation errors, thus reducing the computing time and enhancing the resilience of the cyber physical system. While Liu et al particularly investigated a finite horizon state estimation problem for a class of discrete-time stochastic systems with data random transmission delays and out-of-order packets. They employed an event-driven signal choosing scheme, a synthetic system model can be built, based on which a novel minimum error covariance matrix for the augmented state-space is obtained, and an estimation based compensation approach for random transmission delays is thus proposed to improve the estimation performance. On the other hand, bad data detection is traditionally used in power systems to avoid faulty measurements caused by their anomaly, and hence can ensure the security of state estimation of power systems. However, such as a method is found vulnerable to malicious data deception attacks submerged in big data. Such attacks can purposely craft sparse measurement values (i.e., attack vectors) to mislead power estimates, while not posing any anomalies to the BDD. Du et al consider the case where the attacker generate attack vectors with less sparsity to evade conventional bad data detection, while using a convex optimization method to balance sparsity and magnitude of attack vectors. They investigated the effects of such an attack on the operation costs and risks of power systems, and revealed that by using a security evaluation of individual measurements, such attacks can be detected with a high probability by just securing one critical measurement. Among all possible cyber-attacks, the denial of service is one of the most common attacks in the cyber physical systems. Shen et al studied the load frequency control of one-area power system under denial of service attacks. They show that by integrating the event-triggering control with the load frequency control, the impact of denial of service attacks can be significantly alleviated.

Finally, the energy policy plays an important role in bolstering technological innovations to achieve 100% clean and renewable transition for all sectors. An et al investigated the renewable portfolio standard with tradable green certificate scheme. They proposed a two-stage joint equilibrium model based on the oligopolistic competition equilibrium theory, leading to the formulation of an equilibrium problem with equilibrium constraints which is then solved by a nonlinear complementarity approach. Their case studies reveal that the renewable portfolio standard with tradable green certificate scheme has a profound impact on the market equilibrium outcomes and generation firms' strategic behaviours.

In summary, this themed issue samples the latest research on the control engineering applications in shaping the low carbon energy future, aiming to stimulate future more innovative techniques to foster 100 percent clean and renewable transitions for all sectors. I would like to thank all the authors in this themed issue for the contributions of their latest papers, and all reviewers and editors for their professional supports.

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Executive Editor of the themed issues

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