Guest Editorial:
Special Issue on Computational Intelligence for Smart Energy Applications to Smart Cities

By 2050, more than half the world’s population is expected to live in urban regions. This rapid expansion of population in the cities of the future will lead to increasing demands on various infrastructures; the urban economics will play a major role in national economics. Cities must be competitive by providing smart functions to support high quality of life. There is thus an urgent need to develop smart cities that possess a number of smart components. Among them, smart energy is arguably the first infrastructure to be established because almost all systems require energy to operate.

Smart energy refers to energy monitoring, prediction, use or management in a smart way. In smart cities, smart energy applications include smart grids, smart mobility, and smart communications. While realizing smart energy is promising to smart cities, it involves a number of challenges.

By using smart grid technologies, distributed power supply is replacing conventional centralized schemes, leading to regional aggregation of energy that must consider the interests of many grid participants. With the increasing penetration of electric vehicles (EVs), EV charging stations must consider many parameters and objectives to optimize the charging schedule. To make transportation or communications infrastructures go green, renewable energy sources are often integrated into the whole system as part of power supply; a robust prediction for both power load and energy production becomes necessary for later energy management in response to intermittent power supply from renewable energy sources.

Owing to the uncertainty of environments, complexity of the problem of interest, or multiplicity of objectives that must be achieved, conventional optimization methods using deterministic search algorithms cannot well address these challenges. By contrast, stochastic optimization can be useful for handling uncertainty; adaptive learning based on, for example, human behaviors, available resources, network capacity, or collected data can be a solution to complex problems; evolutionary computation can be applied to solve problems with many objectives. Computational intelligence (CI) thus serves as a useful tool for addressing the aforementioned difficulties.

This special issue aims to provide in-depth CI technologies that enable smart energy applications to smart cities. As guest editors, we are grateful to authors for submitting their original work and making a huge contribution to this special issue. These papers covered a wide range of topics from energy management for a residential community to that for microgrids, and from CI inspired demand response for Internet of EVs to joint energy and quality-of-service-aware scheduling for machine-to-machine communications.

The first paper entitled “Collaborative Energy Management for a Residential Community: A Non-Cooperative and Evolutionary Approach” investigates a non-cooperative Stackelberg equilibrium problem at the level of an aggregator and a multiobjective optimization problem at the level of residential customers. The overall scheme consists of energy suppliers, a community aggregator, and residential customers. The aggregator desires to minimize the overall expected cost through the optimization of customers’ energy demand and its energy storage strategies. Residential customers desire to minimize their expected cost, discomfort, and appliance interruption. Owing to various constraints, coupled decision variables, and non-differentiable objectives, conventional optimization methods are not applicable. A genetic algorithm is thus proposed to solve a problem of collaborative bidirectional energy trading and appliance scheduling in a residential community.

The study involves several elements in the demand response for a residential community, including the consideration of peak-to-average ratio of the power grid, ventilation and air-conditioning appliances, penetration of EVs, energy management system (EMS), distributed generation such as a photovoltaic system, and management of a hot water tank. These elements are critical to the realization of smart energy applications and make the scenario practical. Furthermore, the multiobjective formulation can capture characteristics of conflicting objectives in the framework of energy aggregation.

The second paper entitled “ANFIS Microgrid Energy Management System Synthesis by Hyperplane Clustering Supported by Neurofuzzy Min-Max Classifier” discusses the design of EMS based on adaptive neuro-fuzzy inference systems. It considers a residential grid-connected prosumer microgrid that is equipped with an energy storage system and a photovoltaic energy source. The EMS is dedicated to maximizing the profit generated by energy trading, assuming a time-of-use energy policy. The profit can be maximized through the disruption of the prosumer energy balance between the energy storage system and the connected grid. A data-driven procedure for the synthesis of a real-time microgrid EMS based on CI techniques is proposed.

While system uncertainty and ever-changing environments can pose a challenge to pure optimization methods, the paper
adopts an interesting learning approach to EMS synthesis that may address them adequately. A few design approaches to EMS exit. For example, mixed integer linear programming and dynamic programming are capable of producing optimal scheduling for a prosumer over a given time horizon. However, these approaches usually require high-performance prediction algorithms for renewable generators and loads. By contrast, neural networks and fuzzy logic rule-based inference systems investigated in the paper can be more appropriate for real-time EMS decision support.

While the first two papers consider CI technologies for a residential community and microgrid, the following two papers extend them to potential applications involving Internet of EVs and things in smart cities. The third paper entitled “Blockchain and Computational Intelligence Inspired Incentive-Compatible Demand Response in Internet of Electric Vehicles” examines how to leverage the charging and discharging capabilities of Internet of EVs so that demand response can be implemented in smart cities to enable intelligent energy scheduling and trading. In this article, EVs and local energy aggregators are considered as two major entities. EVs can either act as a responsive load or an energy source; local energy aggregators can provide energy trading related services including real-time data collection, status monitoring, and charging and discharging coordination.

The paper discusses an emerging technology: consortium blockchain. A consortium blockchain-enabled secure energy trading framework with moderate cost is proposed. A contract theory-based incentive mechanism is adopted to incentivize more EVs for participation in demand response. This mechanism is based on the maximization of the social welfare. Optimal contract designs with and without information asymmetry are presented. CI based state of charge estimation techniques are explored.

The fourth paper entitled “Joint Energy and QoS-aware Memetic-based Scheduling for M2M Communications in LTE-M” investigates CI technologies for Internet of Things in long term evolution (LTE) cellular networks. While a large number of machine-to-machine nodes are infrequently uploading data with different packet sizes, the LTE network bandwidth only provides a fixed number of resources dedicated to data transmission for machine-to-machine devices in each millisecond.

The paper proposes a cross-layer scheme in which packet scheduling in time and frequency domain is considered. A memetic-based algorithm is employed to optimize resource allocation of node devices in consideration of their quality of service and energy consumption. A scenario in which the number of resource blocks is higher than the number of active devices is considered as well; a sub-optimality problem is investigated and an algorithm is developed accordingly.

We hope this special issue sheds some light on CI technologies for smart energy applications to smart cities and inspires some impactful research in related fields. Meanwhile, we are aware that this special issue does not cover all relevant topics. Missing topics include: evolutionary computation for smart grids in consideration of many objectives, such as those pertaining to demand-side management, advanced metering infrastructure, or behind-the-meter applications; stochastic optimization for smart mobility in consideration of system uncertainty; CI based demand response for commercial and industrial customers; and machine/deep learning for renewable energy forecasting or power load forecasting. We look forward to more research conducted in these directions and possible collaborations with you in the near future.
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