Guest Editorial Special Issue on Intelligent Energy Solutions to Sustainable Production and Service Automation

ENERGY places an important role in a new scale of urbanization, digitization, and industrialization. Going "energy-efficient" then becomes a major component of the missions for manufacturers and service providers to stay globally competitive. In recent years, the newly emerging intelligent technologies are enhancing the production process and control management in an energy-effective and -efficient manner. In order to apply and implement these innovations, many new challenges and opportunities have emerged and significantly expanded the scopes of typical production and service automation.

The primary objective of this Special Issue is to reflect the intelligent energy solutions to sustainable production and service automation with the focus on information-technology-based modeling, analysis, control, and optimization. For this Special Issue, 15 articles from 35 submissions have been selected for publication after a thorough peer-review according to the standards of the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING.

I. ARTICLES IN THE SPECIAL ISSUE

1) "Robust optimal energy management of a residential microgrid under demand and renewable power generation uncertainties"

The article by Hosseini *et al.* presents a novel robust framework for the day-ahead energy scheduling of a residential microgrid under demand and renewable power generation uncertainties. A min–max robust problem is first formulated to find the optimal scheduling of controllable loads as well as charging/discharging strategies of the energy storage system and the plug-in electric vehicles, which is then transformed into a mixed-integer quadratic programming (MIQP) problem to solve the equivalent robust counterpart of the scheduling problem. The simulation results verify the effectiveness and robustness of the proposed energy scheduling in the uncertain context.

2) "Energy optimization of large-scale AGV systems"

In this article, Riazi *et al.* propose a short-term planning heuristic to schedule the tasks and manage the speed of automated guided vehicles in large networks. The objective is multipurpose, i.e., the minimization of makespan, lateness, and tardiness and energy. An experimental energy model of an automated guided vehicle is developed and used in their proposed heuristic. Results on a real case study, provided by Volvo Cars, show that relevant amount of energy can be saved without deteriorating the other performance measures.

3) "Robust energy management for a corporate energy system with shift-working V2G"

The article by Dai *et al.* presents a two-stage robust optimization model for energy management in a corporate energy system (CES) coordinated with a shift-working vehicle-to-grid (V2G). The first stage focuses on classical CES scheduling, while the second stage proposes an analytical solution that equivalently converts the robust V2G dispatch problem into a single-layer mixed-integer linear programming (MILP) model, aiming to minimize total energy cost. Comprehensive numerical tests are performed based on an iron and steel plant in Shanghai China. The results show that V2G integration can significantly improve the load tracking ability of CES and help reduce the energy cost.

4) "Aggregation of V2H systems to participate in regulation market"

The article by Nakano *et al.* deals with ancillary services for maintaining power grid stability due to the increasing adoption of variable renewable energy resources. The authors develop a new vehicle-to-home (V2H) aggregator that allows individuals to participate in a regulation market using the in-vehicle batteries of their electric vehicles or plug-in hybrid vehicles. The V2H aggregator considers the individual consumption behavior and various constraints, in which a model predictive control scheme is formulated for planning the optimal power profile, aggregation, aggregator bidding, and balancing control to respond to regulation signals. The results show that the proposed V2H aggregator can successfully supply predictable power to the power grid and maximize the profits of individual market participants.

5) "A computing budget allocation method for minimizing EV charging cost using uncertain wind power"

The article by Jiang *et al.* investigates a computing budget allocation problem for minimizing EV charging cost in the context of uncertain wind power. In this article, the authors first use numerical experiments to show the risk of obtaining a bad policy due to imprecise wind power forecasting information, and then apply two existing methods to address this issue,

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namely, the optimal computing budget allocation for maximizing the probability of correct selection (OCBA PCS) and the optimal computing budget allocation for minimizing the expected opportunity cost (OCBA EOC). Numerical results show that OCBA EOC is little better than OCBA PCS and both of them outperform the equal allocation method in the small-scale and the large-scale scenarios.

6) "Multistep prediction-based adaptive dynamic programming sensor scheduling approach for collaborative target tracking in energy harvesting wireless sensor networks"

The article by Liu *et al.* presents a novel multistep prediction-based adaptive dynamic programming (MSPADP) approach for collaborative target tracking in energy harvesting wireless sensor networks to schedule sensors over an infinite horizon. An improved decision tree scheme is implemented for the multistep sensor scheduling, and a three-layer NN is used to obtain the approximate optimal performance for the following infinite steps. Simulation results show that MSPADP can achieve superior tracking performance compared with three existing sensor scheduling approaches.

7) "An online policy for energy-efficient state control of manufacturing equipment"

The article by Frigerio *et al.* proposes an online control policy for machine on/off switching with uncertain part arrival. A time-based algorithm is then developed to provide the optimal control parameters based on online data collection. The numerical analysis shows that the proposed online approach can effectively be applied in real industrial cases by the use of a general estimation method. By tuning the algorithm parameters, the proposed policy is able to cover from the risk of unexpected high-energy consumption and to limit the number of changes in control parameters over time.

8) "Energy efficiency modeling for configuration-dependent machining via machine learning: A comparative study"

The article by Xiao *et al.* investigates the use of machine learning techniques to predict energy efficiency in machining. Indeed, the difficulties in building either physical models that are general enough for different machine tools, or statistical models that can match with multidimensional and collinear data, pave the way to an effective use of machine learning. The authors compare the most relevant machine learning techniques applied to predict the energy efficiency of machine tools in different conditions of tool wear and spindle motor age. Results show that reliable prediction models can be developed if relevant phenomena such as wear and aging of equipment are included, this might be counterbalanced by an increase of complexity in the model-building phase.

9) "Biobjective task scheduling for distributed green data centers"

In this article, Yuan *et al.* study the scheduling of distributed green data centers, which consist of a large set of high-performance servers that intensively use energy to provide services to global users. The used energy may come from different renewable sources such as solar panels and wind turbines as well as standard power grid. The scheduling of tasks seriously affects the performance of these data centers. The authors propose an optimization method to maximize the profit and minimize the average task loss possibility by considering the energy consumption and supplier models. The application of the method on a real data set shows the potential impact of this work in practice.

10) "An approximation algorithm for unrelated parallel machine scheduling under TOU electricity tariffs"

The article by Pei *et al.* presents an approximate scheduling algorithm for unrelated parallel machines in a manufacturing system, which considers time-of-use (TOU) electricity price. A biobjective optimization problem aiming to minimize both the electricity cost and makespan is formulated as a mixed-quadratic integer programming (MQIP) model. The MQIP model is then solved by second-order conic programming reformulation and a series of tailored valid inequalities. An approximate algorithm together with a lower/upper bound method is proposed to further bridge the gaps between the optimal solutions. Results highlight a practical application of the approximate algorithm in generating near-optimal scheduling plans to save energy and maintain productivity.

11) "Multiobjective differential evolution algorithm for solving robotic cell scheduling problem with batch-processing machines"

In this article, Wu *et al.* study robotic cells in manufacturing, which consist of one or more robots used for part movements in the system. They deal with the robot scheduling problem in the case of batch processing machines that are in general time-consuming. Batch processing machines are also very expensive in their investment and operation, therefore the robot must be efficient and avoid to starve or block such machines. Two objectives are addressed in the formulated problem: makespan and energy minimization. The solution method is a meta-heuristic and it has been applied on a set of randomly generated instances to produce Pareto efficient frontier.

12) "Problem formulation and solution methodology for energy consumption optimization in Bernoulli serial lines"

In this article, Yan and Zheng investigate an energy consumption optimization problem in Bernoulli serial production lines with more than two machines by controlling individual machines' efficiencies. The authors formulate the problem as a nonlinear programming to minimize energy consumption of the entire line. Due to difficulties in solving the constrained nonlinear programming problem, a recursive solution method is developed based on the analysis of the Bernoulli line structure and properties. Numerical experiments reveal that compared to the existing heuristic method in the literature, the proposed method can achieve better optimal results.

13) "A multiobjective disassembly planning for value recovery and energy conservation from end-of-life products"

Demanufacturing to recover value and conserve energy from end-of-life (EOL) products for sustainable manufacturing is the topic of the article by Ren *et al.* A multiobjective disassembly planning (DP) problem is formulated, which integrates the decisions on disassembly sequence and EOL strategy to

maximize recovered value and energy conservation from EOL products. The problem is solved through an adapted multiobjective artificial bee colony (MOABC) algorithm. A real-world case study demonstrates that the proposed approach can provide computational efficient and high-quality disassembly solutions that consider the EOL options and energy savings in demanufacturing.

14) "Multiresource-constrained selective disassembly with maximal profit and minimal energy consumption"

The article by Guo *et al.* considers a multiobjective resource-constrained disassembly optimization problem modeled with timed Petri nets for minimum energy consumption and maximum disassembly profit, which is solved by a multiobjective genetic algorithm based on an external archive. The effectiveness of the proposed approach is verified by comparing it with nondominated sorting genetic algorithm II and a collaborative resource allocation strategy for multiobjective evolutionary algorithm based on decomposition. The obtained solutions can be used to guide decision-makers in making better decisions when real products are disassembled.

15) "Revenue and energy cost-optimized biobjective task scheduling for green cloud data centers"

In the last article by Yuan *et al.*, distributed green data centers are analyzed from a different perspective. In this work, the authors investigate the trade-off between providers' revenue and energy cost. In their study, factors such as prices of electricity, availability of renewable power generation, and service level agreements are taken into account. An evolutionary algorithm is proposed to solve the formulated multiobjective optimization problem.

II. Concluding Remarks

This Special Issue has greatly benefited from the cooperation among the authors, reviewers, and editors. We would like to express our sincere thanks to the reviewers for their excellent and timely refereeing. Last, but not least, we thank all authors for their contributions, which made this Special Issue possible.

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