Methods and Systems for a Smart Energy City

CITIES and urban regions are becoming smarter thanks to the recent developments of digital technologies, smart control, data analytics, and optimization concepts. A smart city is equipped with different electronic elements employed by several applications. The utilization of the aforementioned technologies and approaches can furnish intelligent management of energy distribution and consumption in heterogeneous circumstances. Intelligent nodes have some abilities, such as sensing and networking, which raise the possibility of optimal scheduling of energy suppliers. Digitalization can result in the generation of some services that have an interaction with the environment. Hence, it could introduce some opportunities for contextualization and geoawareness. Furthermore, collective intelligence will improve the processes of decision making and empower the citizens. One of the main features of a smart city is due to its ability of favoring customers' responsiveness and efficiency decisions.

A broad range of challenging problems and issues related to the area of smart energy cities and regions is, therefore, being addressed within this Special Section on "Methods and Systems for a Smart Energy City" of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS. Recent research and technology development trends, methods, and corresponding results are being covered by the included contributions of this Special Section, which is technically supported by the Technical Committee on Smart Grids (TC-SG) of the IEEE INDUSTRIAL ELECTRONICS SOCIETY.

In a strict peer-review process supported by highly reputed international experts from the domain, finally, 27 excellent contributions out of around 60 submissions have been selected for publication in this Special Section. They address a wide range of challenging and interesting topics in the domain of smart energy cities, which can be mainly grouped into six clusters related to the following:

1) energy management and optimization problems;
2) demand response approaches;
3) energy market concepts;
4) microgrid control;
5) energy storage systems applications;
6) metering and sensor technology.

Table I provides a brief overview of the assignment of the papers to the aforementioned clusters. In the following, the main content and contributions of these papers are briefly summarized in order to give the readers guidance through the content of this Special Issue.

The first set of articles is related to energy management and optimization problems. In [item 1) in the Appendix], a method for the optimization of the energy-supply in residential premises is proposed, which uses mixed integer linear programming. The characteristics of the electricity as well as the heat consumption and also weather conditions are considered in this concept. Furthermore, an adaptive and robust day-ahead optimization technique for urban energy systems is proposed in [item 2) in the Appendix]. The focus of this concept is on the co-optimization of the day-ahead energy-reserve dispatch and the real-time energy balancing regulation. In [item 3) in the Appendix], a method for analyzing the flexibility of appliances using smart plugs as part of an home energy management system is proposed. The approach is taking care that the users comfort level is being kept on an acceptable level. The concept of energy hubs for smart cities is the topic of [item 4) in the Appendix], where the proposed approach solves the optimal energy flow in order to minimize costs. Mainly, power and gas grids are covered in the corresponding examples. For maintaining the power balance in power systems, a frequency regulation service method using appliances, such an air conditioners, is introduced and discussed in [item 5) in the Appendix]. In [item 6) in the Appendix], a hierarchical approach for the estimation of residential electrical generation, with focus on solar photovoltaic systems and demand models based on hierarchical data, is discussed. The concept uses at first a clustering approach for the hierarchical dataset and estimates in a second step the generation and demand models using kernel regression. Furthermore, in [item 7) in the Appendix], a load-forecasting algorithm using neutral networks is introduced. In contrast, in [item 8) in the Appendix], a MATLAB/Simulink-based residential load simulator toolbox for studying different concepts and methods for residential energy management systems is introduced. This toolset includes different models for various components of an energy management

TABLE I
TOPICS AND INCLUDED PAPERS OF THE SPECIAL SECTION

Topic	Items
Energy management concepts, scheduling, and optimization approaches	items 1)–8) in the Appendix
Demand response programs and demand side management approaches	items 9)–12) in the Appendix
Energy market concepts and trading methods	items 13)–15) in the Appendix
Microgrid-based operation and control; microgrid-related applications	items 16)–19) in the Appendix
Energy storage systems concepts and technologies	items 20)–22) in the Appendix
Metering, measurement, and sensor technologies and algorithms	items 23)–27) in the Appendix

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system but also user-friendly interfaces for the modeling of use cases and examples.

The next set of papers are related to demand response and demand side management approaches. Therefore, in [item 9) in the Appendix], a demand response method is introduced for independent system operators, considering various operation constraints using stochastic programming. Moreover, a framework for integrating fluctuating generation from renewables in heat and electricity energy systems using demand response schemes is covered by [item 10) in the Appendix]. In comparison, a direct load control planning approach for residential end-users is studied in [item 11) in the Appendix]. In this method, heating, ventilation, and air conditioning devices are used for the corresponding demand response scheme. However, an intraday resource trading framework for power grid operators is discussed in [item 12) in the Appendix]. In this approach, demand response resources from different sectors are brought to the system's level, which is used by the grid operator along with traditional generators.

The topic of energy markets and trading approaches is covered by the next three contributions of this Special Section. In [item 13) in the Appendix], a geometric-based clustering and truthful auction schemes for local energy markets in smart cities and energy communities are proposed. The method takes distributed energy resources and prosumer behavior into account. In addition, an optimization method is discussed in [item 14) in the Appendix], which addresses distributed energy resource aggregators in a day-ahead market. Moreover, in [item 15) in the Appendix], a market-based approach for operating a cluster of microgrids with a significant share of intermittent distributed energy resources is proposed.

Microgrid-based concepts and corresponding control approaches are discussed by the next set of articles. In [item 16) in the Appendix], a technique is described and discussed that focuses on the cooperative optimization and economic dispatch of electric vehicles connected for charging in microgrid systems. The proposed method uses particle swarm optimization in order to reduce the total costs of the microgrid operation and the vehicle charging. A study for the distributed load sharing under false data injection in microgrids is presented in [item 17) in the Appendix]. Besides the aforementioned concepts, an optimal scheduling and operation technique of reconfigurable microgrid topologies is introduced in [item 18) in the Appendix]. The proposed approach takes also line rating limitations during grid-connected and islanded mode into consideration. The last microgrid-related contribution targets the operation of islanded microgrids using battery storage systems and renewables in [item 19) in the Appendix]. The proposed scheduling algorithm uses mixed integer linear programming.

The emerging area of energy storage systems and their usage in power and energy systems, especially also in residential and urban areas, are covered by the next three papers. In [item 20) in the Appendix], a method for the analysis of the ageing of lithium-ion batteries is introduced and discussed. The corresponding algorithm uses fractional order models for identifying the degradation state of the storage system. Furthermore, the useful life prediction of lithium-ion batteries is covered in [item 21) in the Appendix]. The corresponding technique uses Box-Cox transformations and Monte Carlo simulation methods. Finally, in [item 22) in the Appendix], an approach is presented, which optimizes the participation of energy storage systems in various electricity markets using portfolio theory. The goal of this method is to reduce risks and maximize benefits for the storage system owners.

The last set of contributions to this smart energy city Special Section is addressing metering systems and sensor technologies for corresponding smart applications. In [item 23) in the Appendix], smart meter information and corresponding data are being used for the peak load estimation in context of smart cities. Moreover, sophisticated devices like microphasor measurement units and corresponding data analytic methods are being used in [item 24) in the Appendix] to detect and analyze faults in urban power and energy system applications. Also, the communication infrastructure for the measurement and sensor technologies used in smart city applications plays and important role. Therefore, in [item 25) in the Appendix], a low-power wireless communication approach is being discussed. In addition, in [item 26) in the Appendix], a structured methodology and a novel communication framework are introduced, which can be integrated into residential smart metering devices. The proposed approach also addresses cyber-security issues. The last paper of this Special Section discusses an approach for electric-field measurements applied to power and energy systems in [item 27) in the Appendix]. The proposed technique uses an optical sensor and piecewise transfer functions.

Summarizing, there are a lot of challenging problems and issues that need to be solved before transforming cities and urban areas into sustainable regions. Sophisticated energy management approaches, corresponding demand response methods and algorithms, energy market, and trading concepts are promising potential methods and tools to overcome those issues. Moreover, microgrid-based architectures as well as the integration of renewables and energy storage systems provide additional possibilities that are helpful besides metering and sensor technologies as covered by the contributions of this Special Section.

However, the readers of this Special Section have to be aware that only a limited part of ongoing latest research activities and trends related to smart energy cities and regions can be covered by the above-mentioned articles. The Guest Editors hope that this Special Section will stimulate and contribute to further ongoing discussions and interesting research work in the above outlined challenging energy-related fields.

Finally, the guest editors wish the readers an enjoyable reading of all articles included in this Special Section.

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APPENDIX
RELATED WORK

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