SMART ENERGY MANAGEMENT IN THE CONTEXT OF INDUSTRY 4.0

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Abstract. In view of the energy crisis, which is also strongly affected by recent geopolitical developments, energy security and sustainability are more significant than ever. To this end, the Industry 4.0 approach along with cutting-edge technological trends which advance in its context are expected to transform energy management for energy consumption in more efficient and sustainable ways. This paper overviews these Industry 4.0 technological trends which can enable smart energy management and identifies some of the corresponding challenges regarding this issue.

1. Introduction

Energy is a critical factor which considerably defines several elements of human activity and globally affects the economic and social development in general [1]. Taking into account that economic growth is strongly tied to energy consumption [2], the rising economic development in recent decades has led to an exponential demand in energy, which is expected to further increase in the near future, leading to major concerns regarding energy and environmental security [3]. In this context, governments, corporations, and other organizations are urged to prioritize agendas regarding energy security and sustainability in order to bring the energy crisis to a halt. The fourth industrial revolution, known as Industry 4.0 (I4.0), is considered to impact the energy potency through the establishment of digitalized infrastructures. Hence, by adopting the cuttingedge technologies which advance in the context of I4.0, energy management is expected to be transformed into "smart" by effectively metering the power and predicting the demand as well as regulating the distribution and consequently optimizing the grid [4]. This approach enhances consequently energy security with regard to sustainable policies. The main scope of this paper is to overview these I4.0 technological trends of which the integration into the energy sector enables smart energy management and identify some of the corresponding challenges regarding this issue.

2. Smart Energy Management towards the Industry 4.0

Deficiencies in conventional power grids, such as inability to predict the demand, lack in efficiently managing the energy distribution, delay in detection of failures, have urged the advance of smart grids (SG) [5]. The primary goal of the SG is the energy supply through the usage of advanced digital technologies offering a variety of advantages toward reliable, cost-effective, and environmentally safe prospects. In this context, the I4.0 digital technologies enable all SG actors to control their energy needs, consumptions, and costs in real-time [6].

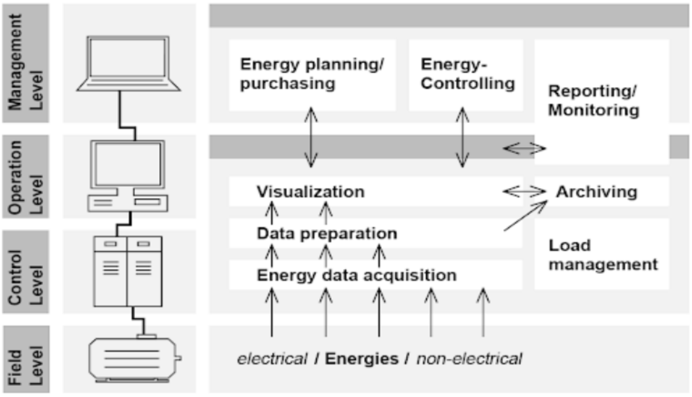

Fig. 1 Smart Energy Management System Architecture [7]

For the implementation of such a corporate policy a multi-level Smart Energy Management System is best to be incorporated, as indicatively shown in Fig. 1 [7]. This results into an energyaware system which through the incorporation of I4.0 technologies is capable of integrating raw energy data into the corresponding industrial processes, performing energy effective and flexible production planning, improving the energy supply and consequently optimizing energy efficiency [8].

3. Industry 4.0 Key Technologies for Smart Energy Management

The key technological trends that are particularly significant for Smart Energy Management, according to the guidelines for the operative implementation of the Industry 4.0, along with their respective capabilities and probable challenges in the context of sustainability policies, are overviewed as follows:

- *Industrial Internet of Things (IIoT):* The Industrial Internet of Things (IIot) paradigm is considered to be the fundamental enabling technology for effective Smart Energy Management while it is currently associated with the development of the smart grid. In particular, the integration of the IIoT into Smart Energy Management allows the overall supervision and regulation of the smart grid with regard to actual energy and production costs permitting the drawing of directions for further optimization. Nevertheless, the IIoT nfrastructure's growing number of connections among smart devices poses significant challenges towards privacy and security, heterogeneity and data standards, reliable communication protocols, tracking and monitoring as well as performance evaluation, maintenance and optimization.
- *Big Data Analytics*: Big data technologies support data model assessment and enhance data management. Given the growing number of data sources in the smart grid due to the widespread integration of smart interconnected devices, the usage of powerful analytics tools capable of interpreting the accumulated data into useful information are an imperative necessity for successful Smart Energy Management. However, challenges impose regarding a) the identification of unexpected correlations, hidden consumption, market trends, and other useful information, b) reliable storage and retrieval of vast amounts of data with regard to the priority of applications and c) the dependability and safety of intelligent decision-making at the appropriate moment for the appropriate purpose.
- *Blockchain:* The integration of blockchain with the smart grid demonstrates its effectiveness in addressing concerns regarding security and privacy, rewarding and disciplinary systems, as well as standardization. Given that it may be used to create more transparent and secure energy systems that benefit both consumers and producers, the integration of blockchain technology in the smart grid is still a hot research area. Although the blockchain is already being used in industry to organize diversified supplies of renewable energy without the involvement of intermediaries, there are several challenges that need to be addressed, turning this technology a hot spot for both academic research and practical applications in Smart Energy Management.
- *Artificial Intelligence (AI) and Machine Learning (ML):* Approaches that provide advanced solutions for Smart Energy Management, refer to incentive-based demand response models, allowing variable involvement levels depending on the load, utilization of deep learning and reinforcement learning techniques to build a real-time incentive mechanism for the smart grid as well as various incentive mechanisms that can be used for smart energy systems.

Conclusions:

It can be concluded, that a combination of the Industry 4.0 technologies is most significant in order to achieve a high degree of real energy efficiency while maintaining high productivity. As a next step, more particular recommendations for suitable strategies depending on specific system characteristics and influencing parameters should be conducted. As the overviewed technological trends embody various characteristics for efficient energy management systems, future work should also examine the economic and environmental consequences of presented energy flexibility strategies.

References:

[1] Glavič P. (2021). Evolution and current challenges of sustainable consumption and production. Sustainability, 13(16), 9379.
[2] Li F., Song Z., Liu W. China's energy consumption under the global economic crisi: decomposition and sectoral analysis Energy Policy, 64 (2014), pp. 193-202 3
[3] Kaygusuz K., Bilgen S. Energy related environmental policies in Turkey Energy Sources Part B, 3 (2008), pp. 396-410
[4] Dileep G. A survey on smart grid technologies and applications. Renew. Energy 2020, 146, 2589–2625.
[5] Triantafyllou A., Jimenez J.A.P., Torres, A.D.R., Lagkas T., Rantos K., Sarigiannidis P. The challenges of privacy and access control as key perspectives for the future electric smart grid. IEEE Open J. Commun. Soc. 2020, 1, 1934–1960
[6] Sittón-Candanedo I., Alonso R.S., García Ó., Muñoz L., Rodríguez-González S. Edge computing, IoT and social computing in smart energy scenarios Sensors, 19 (15) (2019), p. 3353
[7] Smart EAM. Energy management according to Industry 4.0 principles. ttps://smarteam.com/news/jenergomenedzhment-po-principam-industry-4-0/
[8] Wu Z., Yang K., Yang J., Cao Y., Gan Y. Energy-efficiency-oriented scheduling in smart manufacturing J. Ambient Intelligence Humanized Comput., 10 (3) (2019), pp. 969-978