# Smart Grids

Subjects: Control & Systems Engineering
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## Definition

The Smart Grid is a modern intelligent network adapted to a new global paradigm. Intelligent systems bring together energy and information and communication technologies, improving performance, quality, generation, transmission, distribution, and marketing services. Regarding the influence of intelligent networks in the transformation of human activities, it is essential to know the resources and systems of sensors, IoT and, in general, the devices that improve people's quality of life. Today, there is a growing need for society to take care of its health by integrating the use of technology. Human Activity Recognition (HAR) allows monitoring of people's quality of life and, in time, more features and functionalities emerge in this area, relying on a wide repertoire of hardware and software components. Proof of this is the implementation of several solutions in indoor environments, which capture the data generated from people's interactions with an intelligent environment. Data collected from heterogeneous sensors implemented in intelligent environments or from sensors connected to the body (wearables) are stored in datasets and the information obtained from intelligent devices is integrated into a larger set, the intelligent network that brings together an environment, a community, a city, and, in general, a joint strategy to improve the quality of technology and life in our society.

## 1. Introduction

The design of electrical installations in a given environment poses a challenge for the improvement of energy management in our society. In the year 2019, one of the main objectives of the United Nations Climate Change Conference–COP25–held in Madrid was the development and transfer of technology to achieve a sustainable evolution of energy consumption worldwide, with the main objective of reducing greenhouse gas emissions [1].

Today, there is a growing need for society to take care of its health by integrating the use of technology and numerous studies and research efforts offer interesting works on this topic [2][3]. The technology that we design and build in intelligent environments must be a climate-focused technology; that is, technological developments must drive energy consumption through renewable sources, control and measure consumption, reduce greenhouse gas emissions, and alert and prevent inappropriate energy consumption. In short, household technologies should integrate the processes of energy efficiency and environmental sustainability.

Electrical and energy networks in general are designed, planned, and installed with the objective of providing high-quality electricity supply to users. This energy travels enormous distances to reach the final point, which is the consumer. People are essential in this scenario and play a key role in interacting with the energy networks when it comes to designing better installations and improving quality.

The Smart Grid is a modern intelligent network adapted to a new global paradigm. Intelligent systems bring together energy and information and communication technologies, improving performance, quality, generation, transmission, distribution, and marketing services [4][5].

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In 2010, the Conference of the Parties, the supreme decision-making body of the United Nations Framework Convention on Climate Change, established the Technology Executive Committee (TEC) with the objective of accelerating and enhancing the development and transfer of climate technology. This committee consists of 20 experts representing developed and developing countries. The Technology Executive Committee analyses climate technology issues and develops balanced policy recommendations, supporting countries to accelerate action on Climate Change (Figure 1). The Technology Executive Committee brings together a range of institutions, non-governmental organisations, government experts, the United Nations, and others [7].

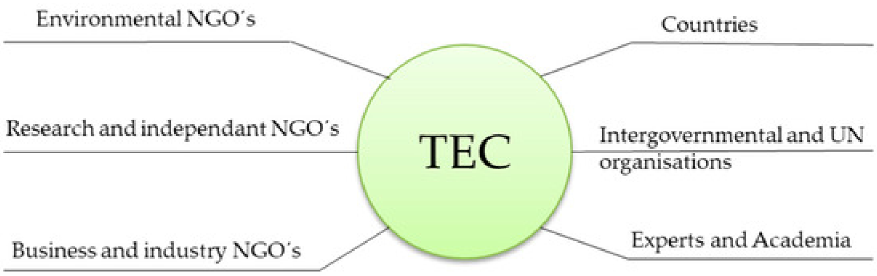

**Figure 1.** Focus areas of the Technology Executive Committee[7].

In 2018, the European Commission published the document: “A Clean Planet for all”. A European strategic long-term vision for a prosperous, modern, competitive, and climate-neutral economy, in which it presented a strategy for the transition to a zero-net-emission economy in 2050. According to the European Commission, the energy system of the future will integrate the systems and markets for electricity, natural gas, air conditioning, and mobility, with smart grids that put citizens at the centre [8].

Technology, and its development, is not only an effective tool in the fight against climate change, but it is also an essential mechanism for the evolution of life on earth and the improvement of human health and the condition of the planet in general. Technological design in this context will be key to the future of humanity.

The technological design of the environments where we live, move, and work must also be the subject of a detailed analysis related to climate technology. Human beings produce and emit greenhouse gases as a product of our activity; hence we must design sustainable and efficient spaces.

The design of smart homes and houses must be adapted to existing regulations on electrical engineering and automation. These regulations have become obsolete and are sometimes not suitable for efficient and sustainable climate design. As is often the case, technological research and innovation are evolving faster than regulations [9][10]. Based on the above, in this work, we will focus on studying the interaction between intelligent systems integrated in human environments and the recognition of human activities that can be observed in such spaces in a multidisciplinary way, with the purpose of carrying out a systematic and comprehensive review of the existing research in this field and contributing new ideas to these advances [11][12].

## 2. Results

### 2.1. Quantitative Analysis

We begin this point by indicating that a time frame of full years has been chosen, from 2015 to 2019. In the year 2020, at the date of completion of this work, there are some very interesting references related to our research, but because they do not comply with the time parameter, they have not been included in the data tables and quantitative and qualitative analyses. A total number of 29 works that could meet the objectives of this research have been located in the databases analysed. The work done by Dileep can be highlighted [13], as it offers a comprehensive and detailed analysis of all the components of the intelligent network, its applications, benefits, and opportunities, also taking into account the importance of the users.

We continue analysing Table 1, where it can be seen that 481 results were obtained in the first block of data extraction, while applying the corresponding filters resulted in a lower number, 180 results. The first column indicates the name of the analysed database, the second column, Results, indicates the number of gross results obtained. The columns for Filter 1, Filter 2, and Filter 3 present the screening results. In the last column, Revised Results, all 180 results are included.

**Table 1.** Summary of search results and filters.

| | Library | Results | Filter 1 | Filter 2 | Filter 3 | Revised Results | Duplicates | | Revised Results Final |
|---|---|---|---|---|---|---|---|---|---|
| **Search String Model** | IEEExplore | 129 | 74 | 72 | 0 | 72 | IEEExplore + WOS + SCOPUS | 3 | |
| | WOS | 34 | 23 | 22 | 0 | 22 | IEEExplore + WOS | 9 | |
| | SCOPUS | 318 | 165 | 155 | −69 | 86 | IEEExplore + SCOPUS | 6 | |
| **Total** | | 481 | 262 | 249 | −69 | 180 | | 18 | **162** |

By filtering out the works that are repeated over several databases, we obtain the final number of articles to be reviewed in a qualitative way, this being 162.

As we can see in Figure 2, representing the results from the Scopus database, there is a remarkably large percentage of articles in the areas of Computer Science (41.1%) and Engineering (35.9%). These data coincide approximately with those of the WOS and IEEExplore databases.

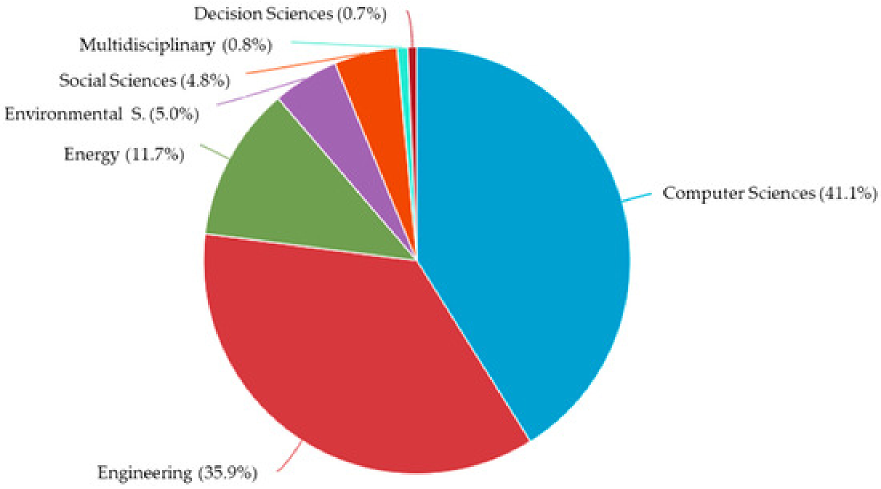


**Figure 2.** Analysis of the Scopus database results by area.

## 2.2. Qualitative Analysis

### 2.2.1. Analysis Strategy 1. SG Architectures, Models and Studies

There are numerous sources that propose their work as an analysis of architectures, models, prototypes, and studies on SGs and their relationship with communication systems for the automation of low-voltage electrical networks in intelligent indoor environments.

If we analyse the documents [14][15][16][17][18][19][20][21][22], we find relationships between the fields of work studied. For example, a multi-zone control scheme for data and energy flow management was designed and evaluated in [14] using real data on load demand and energy prices from the household power grid. A reduction in energy demand was deduced.

In the IEEExplore database, some works in the field of SGs, sensors, and applications in the intelligent home have been selected to be studied [23][24]. In [23], educational training in SGs and the use of advanced sensor technologies are analysed. This document presents a test bed in the smart home based on the project-based learning (PBL) pedagogical model for undergraduate education. The proposed test bench enables undergraduate students to gain key skills in smart network-related topics such as peak demand flattening, real-time price response, wireless sensor networks, machine learning, pattern recognition, embedded system programming, user interface design, circuit, and database design.

There is some interesting research in the Scopus database, where[25] proposes a new energy management approach to smart homes that combines a wireless network based on Low-Energy Bluetooth (BLE) for communication between home appliances with a Home Energy Management (HEM) scheme. People's comfort is taken into account when it comes to intelligent and integrative energy management. Figure 3 shows a proposal for a home network with sensors based on Bluetooth.

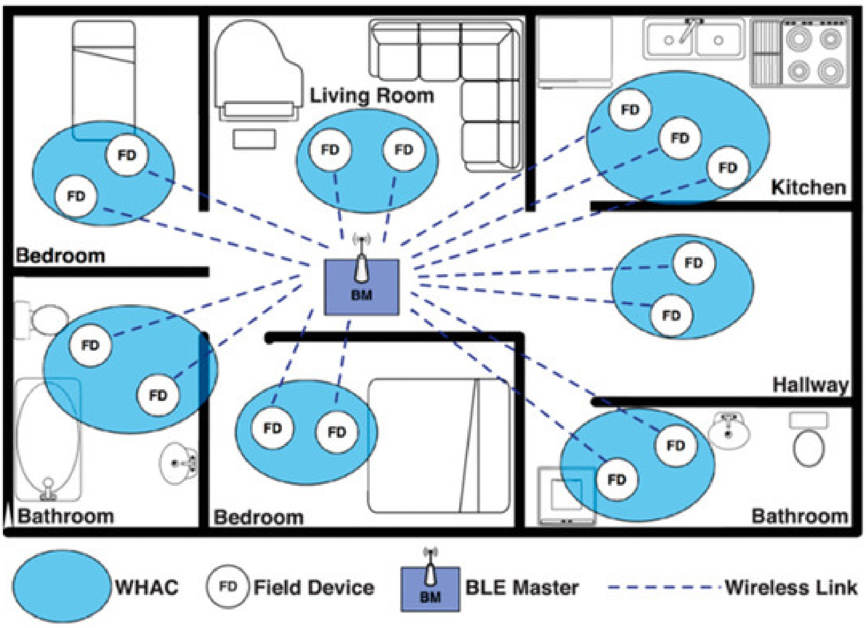


**Figure 3.** Proposal for a home network with sensors based on Bluetooth[25].

#### 2.2.2. Analysis Strategy 2: Modelling Control Theory, Mathematical Analysis, Block Diagrams, Differential/Integral Equations

If we propose an analysis of the works that contain research on control theory modelling, mathematical analysis, etc., that are an essential part of developments in the field of study of SGs concerned with integrated sensors in the home, we find the following references that carry out similar studies: [26][27][28][29][30][31][32][33][34][35].

One interesting aspect that needs to be addressed is that which is referred to in[28] and which in this era has grown considerably—the field of cyber security. In this document, we analyse IoT-enabled cyberattacks, which can be found in all fields of application.

Three objectives are proposed: (1) To evaluate IoT-enabled cyberattacks with a risk-based approach, (2) to identify hidden and subliminal attack routes enabled by IoT against critical infrastructures and services, and (3) to examine mitigation strategies for all fields of application. In analysing SGs and their application to HAR, we must take cyber security into account.

Wazid [31] studies a new efficient protocol for remote user authentication in the implementation of IoT and also evaluates the formal security verification of the scheme by automatically validating the Internet Security Applications and Protocols Tool (AVISPA) through simulation to verify whether it is secure (Figure 4).

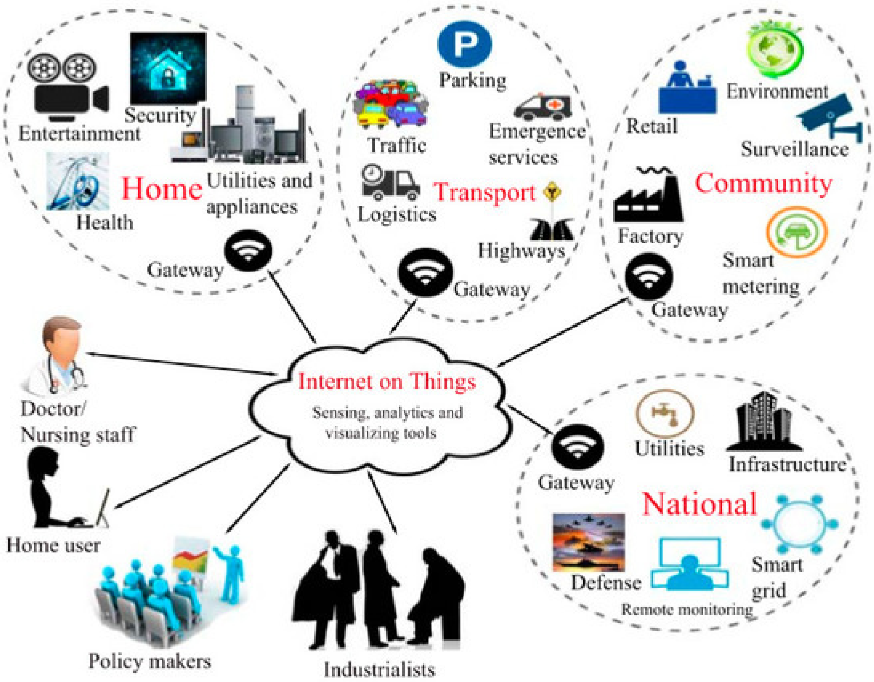


**Figure 4.** Network architecture Internet of Things (IoT) [31].

#### 2.2.3. Analysis Strategy 3: SGs and Their Application to HAR and ADL

The results of a study carried out in 19 Scottish households in which energy consumption and the perception of SGs in relation to energy were controlled by means of sensors and equipment installed in these homes, mainly in homes inhabited by older people, are presented in [36]. This applies a social scope to the study, a case that interests us, since one of the objectives of the work we are analysing is social involvement, applying the study and its results to households and elderly people in future applications.

In reference [37], an analysis of civil applications, prototypes, and possibilities for future integration of the wireless sensor is carried out by means of a bibliographic review, discussing human life and welfare. It classifies the use of wireless sensors in different disciplines and makes specific mention of those related to human health and human use for HAR.

We can observe that in the filtering of documents and research works, in this case for studies related to SGs, sensors, and devices that facilitate, study, or research human activities, mobility in intelligent environments, etc., we find few works that interrelate these subjects.

We would have to apply other search parameters to find further research in this field, but we wanted to analyse the fact of direct studies with people, with mobility within the home of people with disabilities, elderly people, and other types of search vectors being largely absent when searching for the terms SGs or intelligent networks.

This will lead us to the conclusion presented at the end of the work, in which we analyse this fact.

#### 2.2.4. Analysis Strategy 4: Simulation of Intelligent Environments with Sensors in the Home, Data Control Architecture, Complex Computer Systems

In [38], the relationship of SGs assisted by IoT is addressed: Technologies, architectures, applications, prototypes, and directions for future research. It is an interesting and comprehensive work on the more specific field of SGs and their relationship with IoT (Figure 5). However, we still do not see a more direct relationship with the social and human spheres, in order to link this SG strategy with its direct application to HAR and ADL. In this work, the research is focused on structuring the sources of SGs and their relationship with IoT, but it covers a large number of vectors related to the generation, transmission, and marketing of electrical energy, where the home and the application of sensors for the improvement of people's quality of life is scarcely touched upon.

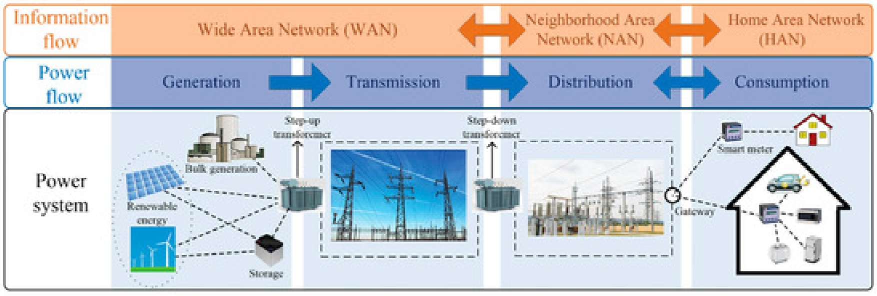


**Figure 5.** Smart Grid architecture featuring power systems, power flow, and information flow[38].

Data privacy and security for the home area network connected to the network using IoT is discussed in[39]. This paper looks into secure data flow and customer data privacy during critical and emergency operations. Data are available in real time with minimal delay in transit time. Devices are continuously monitored for vital and emergency services. User energy consumption data are intended to be available in the cloud and also on customized electronic devices in real time.

Aroua [40] proposes a new framework for household energy control in smart homes using Cognitive Radio Sensor Networks (CRSN).

Andrade, in his work [41], develops a management methodology that analyses the behaviour of wireless networks within an intelligent home through a simulation, taking into account several parameters or restrictions such as coverage distance and capacity. The smart grid infrastructure is described, and a mathematical model is proposed to minimise the distance of the sensors to the access points within the area under consideration.

In [42], optimal energy demand data management for smart homes is studied. The system can support near real-time decisions for 10,000 customers, each of which has 10 sensors with only 35 basic machines running free software in the cloud.

The European project COMPOSE [43], Collaborative Open Market to Place Objects at your Service, analysed the inclusion of sensors inside a supermarket that track the location of shopping carts as customers move through the store, which can then be combined with shopping information. These data can be used to help position the product on the supermarket shelves. This type of research does provide learning to be implemented in the development of HAR studies, however this document does not discuss this aspect, but focuses rather on business production.

The review of communication protocols or algorithms, which study the design and implementation of environments with SG sensors and to a large extent are studies in the field of energy demand, electrical networks, are an important area of research among the following documents analysed: [44][45][46][47][48].

There are also studies that address the role of 5G technology in the IoT[49] and in some others, such as [50], different vectors are studied, such as temperature and $CO_2$ level and its control, to find out how people move around in a home or how they consume. This study developed a methodology to determine individual household occupation patterns using ubiquitous household sensors.

The characteristics were derived from sensors that monitored electrical energy, dew point temperature, and $CO_2$ concentration indoors and merged using the Dempster–Shafer method of combining evidence. A hidden Markov method was then applied to predict the occupancy profile during the day. It is an evidence-based approach.

Wang and others, in [51], discuss a wireless sensor network (WSN) applied in the intelligent network communication system, which is low-cost, low-energy dissipation, self-organising, and highly flexible. This article presents WSN applications in condition-based maintenance, smart metering, and smart homes, among others.

Nguyen [52] makes a practical implementation of an intelligent home system based on a wireless sensor network for the integration of SGs. It presents a SG home gateway hardware design. The SG Home Gateway can control electrical devices according to the programming schedule or data received from the control centre. In addition, it proposes a simple wireless network topology based on the star routing protocol for the SG Home Network. The results of the final demonstration present a SG Home Gateway prototype.

It is interesting to note that the relationship between SGs, sensors, HAR, and ADL has multiple applications and different points of view, which are interrelated and have design and simulation perspectives that portend a very promising future for the benefit of people's health, even more so during this pandemic in which we have undergone lockdowns and where health and technology play an increasingly important role.

## References


1. United Nations Climate Change. Report of the Green Climate Fund to the Conference of the Parties. Conference of the Parties. Technology Executive Committee (TEC). In Proceedings of the Twenty-Fifth Session, Madrid, Spain, 2–13 December 2019; Available online: https://unfccc.int/documents/210472 (accessed on 2 August 2020).
2. AENOR Standards. Standardisation in Intelligent Networks. Smart Grid—Application Specification. Interface and Framework for Customer. UNE-EN 50491-12-1:2019. Available online: https://www.aenor.com/normas-y-libros/buscador-de-normas/une/?c=N0061386 (accessed on 2 August 2020).
3. De la Hoz Franco, E.; Ariza-Colpas, P.; Quero, J.M.; Espinilla, M. Sensor Based Datasets for Human Activity Recognition. A Systematic Review of Literature. IEEE Access 2018, 6, 59192–59210.
4. Ma, Y.; Li, B. Hybridized Intelligent Home Renewable Energy Management System for Smart Grids. Sustainability 2020, 12, 2117.
5. Li, Y. Design of a Key Establishment Protocol for Smart Home Energy Management System. In Proceedings of the 2013 Fifth International Conference on Computational Intelligence, Communication Systems and Networks, Madrid, Spain, 5–7 June 2013; pp. 88–93.
6. Bolleddula, N.; Chun Hung, G.Y.; Ma, D.; Noorian, H.; Woodbridge, D.M. Sensor Selection for Activity Classification at Smart Home Environments. In Proceedings of the 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC), Montreal, QC, Canada, 20–24 July 2020; pp. 3927–3930.
7. Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the Harmonisation of the Laws of Member States Relating to Electrical Equipment Designed for Use within Certain Voltage Limits. Available online: http://data.europa.eu/eli/dir/2006/95/oj (accessed on 5 August 2020).
8. Communication from the Commission to the European Parliament, the Council. The European Economic and Social Committee. A Digital Agenda for Europe. European Commission. EurLex-2010.DC0245. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2010:0245 (accessed on 6 August 2020).
9. UNE-EN ISO 16484-1:2011 Building Automation and Control Systems (BACS). Project Specification and Implementation (ISO 16484-1:2010). Available online: https://www.une.org (accessed on 6 August 2020).
10. UNE-EN 50491-5-2:2010 General Requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS). EMC requirements for HBES/BACS Used in Residential, Commercial and Light Industry Environment. Available online: https://www.une.org/encuentra-tu-norma/busca-tu-norma/norma/?c=N0046285 (accessed on 7 August 2020).
11. Stojkoska, B.L.R.; Trivodaliev, K.V. A review of Internet of Things for smart home: Challenges and solutions. J. Clean. Prod. 2017, 140, 1454–1464.
12. Wang, K.; Yu, J.; Yu, Y.; Qian, Y.; Zeng, D.; Guo, S.; Xiang, Y.; Wu, J. A Survey on Energy Internet: Architecture, Approach, and Emerging Technologies. IEEE Syst. J. 2018, 12, 2403–2416.
13. Dileep, G. A survey on smart grid technologies and applications. Renew. Energy 2020, 146, 2589–2625.
14. Singh Aujla, G.; Garg, S.; Batra, S.; Kumar, N.; You, I.; Sharma, V. DROpS: A demand response optimization scheme in SDN-enabled smart energy ecosystem. Inf. Sci. 2019, 476, 453–473.
15. Ruzbahani, H.M.; Karimipour, H. Optimal incentive-based demand response management of smart households. In Proceedings of the 2018 IEEE/IAS 54th Industrial and Commercial Power Systems Technical Conference (I&CPS), Niagara Falls, ON, Canada, 7–10 May 2018; pp. 1–7.
16. Islam, T.; Mukhopadhyay, S.C.; Suryadevara, N.K. Smart Sensors and Internet of Things: A Postgraduate Paper. IEEE Sens. J. 2017, 17, 577–584.
17. Alharthi, A.S.; Yunas, S.U.; Ozanyan, K.B. Deep Learning for Monitoring of Human Gait: A Review. IEEE Sens. J. 2019, 19, 9575–9591.
18. Maurya, A.; Akyurek, A.S.; Aksanli, B.; Rosing, T.S. Time-series clustering for data analysis in Smart Grid. In Proceedings of the 2016 IEEE International Conference on Smart Grid Communications (SmartGridComm), Sydney, Australia, 6–9 November 2016; pp. 606–611.
19. Vega, A.M.; Santamaria, F.; Rivas, E. Modeling for home electric energy management: A review. Renew. Sustain. Energy Rev. 2015, 52, 948–959.
20. Samantaray, S.R. Editorial Special Issue on Sensors and Data analytics for Smart Grid Infrastructure. IET Gener. Transm. Distrib. 2015, 9, 113–114.

21. Akula, P.; Mahmoud, M.; Akkaya, K.; Songi, M. Privacy-preserving and secure communication scheme for power injection in smart grid. In Proceedings of the 2015 IEEE International Conference on Smart Grid Communications (SmartGridComm), Miami, FL, USA, 2–5 November 2015; pp. 37–42.
22. Bell, S.; Judson, E.; Bulkeley, H.; Powells, G.; Capova, K.A.; Lynch, D. Sociality and electricity in the United Kingdom: The influence of household dynamics on everyday consumption. Energy Res. Soc. Sci. 2015, 9, 98–106.
23. Hu, Q.; Li, F.; Chen, C. A Smart Home Test Bed for Undergraduate Education to Bridge the Curriculum Gap from Traditional Power Systems to Modernized Smart Grids. IEEE Trans. Educ. 2015, 58, 32–38.
24. Morello, R.; Mukhopadhyay, Z.; Slomovitz, D.; Samantaray, S.R. Advances on Sensing Technologies for Smart Cities and Power Grids: A Review. IEEE Sens. J. 2017, 17, 7596–7610.
25. Collotta, M.; Pau, G. A Novel Energy Management Approach for Smart Homes Using Bluetooth Low Energy. IEEE J. Sel. Areas Commun. 2015, 33, 2988–2996.
26. Yu, H.; Shi, L.; Qian, Y.; Shu, F.; Li, J.; Zhao, Y.; Nalin, D.; Jayakody, K. A cooperative modulation recognition: New paradigm for power line networks in smart grid. Phys. Commun. 2017, 25, 268–276.
27. Koutitas, G.C.; Tassiulas, L. Low Cost Disaggregation of Smart Meter Sensor Data. IEEE Sens. J. 2016, 16, 1665–1673.
28. Stellios, I.; Kotzanikolaou, P.; Psarakis, M.; Alcaraz, C.; Lopez, J. A Survey of IoT-Enabled Cyberattacks: Assessing Attack Paths to Critical Infrastructures and Services. IEEE Commun. Surv. Tutor. 2018, 20, 3453–3495.
29. Mosenia, A.; Sur-Kolay, S.; Raghunathan, A.; Jha, N.K. DISASTER: Dedicated Intelligent Security Attacks on Sensor-Triggered Emergency Responses. IEEE Trans. Multi Scale Comput. Syst. 2017, 3, 255–268.
30. Javaid, N. An Intelligent Load Management System with Renewable Energy Integration for Smart Homes. IEEE Access 2017, 5, 13587–13600.
31. Wazid, M.; Das, A.K.; Odelu, V.; Kumar, N.; Conti, M.; Jo, M. Design of Secure User Authenticated Key Management Protocol for Generic IoT Networks. IEEE Internet Things J. 2018, 5, 269–282.
32. Ko, J.; Jeong, J.; Park, J.; Arm Jun, J.; Gnawali, O.; Paek, J. DualMOP-RPL: Supporting Multiple Modes of Downward Routing in a Single RPL Network. ACM Trans. Sens. Netw. 2015, 11, 2.
33. Fadel, E.; Faheem, M.; Gungor, V.C.; Nassef, L.; Akkari, N.; Malik, M.G.A.; Almasri, S.; Akyildiz, I.F. Spectrum-aware bio-inspired routing in cognitive radio sensor networks for smart grid applications. Comput. Commun. 2017, 101, 106–120.
34. Peretti, G.; Lakkundi, V.; Zorzi, M. BlinkToSCoAP: An end-to-end security framework for the Internet of Things. In Proceedings of the 2015 7th International Conference on Communication Systems and Networks (COMSNETS), Bangalore, India, 6–10 January 2015; pp. 1–6.
35. Jurado, S.; Nebot, A.; Mugica, F.; Mihaylov, M. Fuzzy inductive reasoning forecasting strategies able to cope with missing data: A smart grid application. Appl. Soft Comput. 2017, 51, 225–238.
36. Barnicoat, G.; Danson, M. The ageing population and smart metering: A field study of householders' attitudes and behaviours towards energy use in Scotland. Energy Res. Soc. Sci. 2015, 9, 107–115.
37. Nag, A.; Mukhopadhyay, S.C.; Kosel, J. Wearable flexible sensors: A review. IEEE Sens. J. 2017, 17, 3949–3960.
38. Saleem, Y.; Crespi, N.; Rehmani, M.H.; Copeland, R. Internet of Things-Aided Smart Grid: Technologies, Architectures, Applications, Prototypes, and Future Research Directions. IEEE Access 2019, 7, 62962–63003.
39. Manimuthu, A.; Ramesh, R. Privacy and data security for grid-connected home area network using Internet of Things. IET Netw. 2018, 7, 445–452.
40. Aroua, S.; El Korbi, I.; Ghamri-Doudane, Y.; Saidane, L.A. A distributed Cooperative Spectrum Resource Allocation in smart home cognitive wireless sensor networks. In Proceedings of the 2017 IEEE Symposium on Computers and Communications (ISCC), Heraklion, Crete, Greek, 3–6 July 2017; pp. 754–759.
41. Arghandeh, R.; Von Meier, A.; Mehrmanesh, L.; Mili, L. On the definition of cyber-physical resilience in power systems. Renew. Sustain. Energy Rev. 2016, 58, 1060–1069.
42. Frincu, M.; Draghici, R. Towards a scalable cloud enabled smart home automation architecture for demand response. In Proceedings of the 2016 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), Ljubljana, Slovenia, 9–12 October 2016; pp. 1–6.
43. Raggett, D. COMPOSE: An Open Source Cloud-Based Scalable IoT Services Platform. ERCIM News, 1 April 2015.
44. Taylor, R.; Baron, D.; Schmidt, D. The world in 2025-predictions for the next ten years. In Proceedings of the 2015 10th International Microsystems, Packaging, Assembly and Circuits Technology Conference (IMPACT), Taipei, Taiwan, 21–23 October 2015; pp. 192–195.
45. Ahsan, U.; Bais, A. Distributed Smart Home Architecture for Data Handling in Smart Grid. Can. J. Electr. Comput. Eng. 2018, 41, 17–27.
46. Nambi, S.N.A.U.; Prasad, R.V.; Lua, R.A. Decentralized Energy Demand Regulation in Smart Homes. IEEE Trans. Green Commun. Netw. 2017, 1, 372–380.
47. Ma, S.; Liu, Q.; Sheu, P.C. Foglight: Visible Light-Enabled Indoor Localization System for Low-Power IoT Devices. IEEE Internet Things J. 2018, 5, 175–185.
48. Collotta, M.; Pau, G. An Innovative Approach for Forecasting of Energy Requirements to Improve a Smart Home Management System Based on BLE. IEEE Trans. Green Commun. Netw. 2017, 1, 112–120.
49. Borkar, S.G.; Pande, H. Application of 5G next generation network to Internet of Things. In Proceedings of the 2016 International

Conference on Internet of Things and Applications (IoTA), Pune, India, 22–24 January 2016; pp. 443–447.
50. Chaney, J.; Hugh Owens, E.; Peacock, A.D. An evidence based approach to determining residential occupancy and its role in demand response management. Energy Build. 2016, 125, 254–266.
51. Cetinkaya, O.; Akan, O.B. Electric-Field Energy Harvesting in Wireless Networks. IEEE Wirel. Commun. 2017, 24, 34–41.
52. Nguyen, M.; Nguyen, L.; Nguyen, T. A practical implementation of wireless sensor network based smart home system for smart grid integration. In Proceedings of the 2015 International Conference on Advanced Technologies for Communications (ATC), Ho Chi Minh City, Vietnam, 14–16 October 2015; pp. 604–609.

**Keywords**

smart grids;sensors;human activity recognition;internet of things;literature review