Nano World Journal

https://doi.org/10.17756/nwj.2023-s5-057

Review Article

Open Access

Impact of Nanotechnology in the Development of Smart Cities

Govind Murari Upadhyay[1*], Shalendra Kumar[2], Rakhi Chawla[2] and Shashi Kant Gupta[3]

[1]Department of Computer Applications, Manipal University, Jaipur, Rajasthan, India
[2]NDIM, Guru Gobind Singh Indraprastha University, Delhi, India
[3]ITM University, Gwalior, Madhya Pradesh, India

[*]Correspondence to:
Govind Murari Upadhyay
Department of Computer Applications,
Manipal University,
Jaipur, Rajasthan, India.
E-mail: govind.upadhyay@jaipur.manipal.edu

Received: October 20, 2023
Accepted: December 22, 2023
Published: December 28, 2023

Citation: Upadhyay GM, Kumar S, Chawla R, Gupta SK. 2023. Impact of Nanotechnology in the Development of Smart Cities. *NanoWorld J* 9(S5): S313-S318.

Copyright: © 2023 Upadhyay et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY) (http://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

The term "smart city" refers to a hypothetical metropolitan setting where cutting-edge technology is used to improve productivity, sustainability, and the standard of living for locals. In this setting, nanotechnology has become a game-changer by providing novel approaches to difficult urban problems. The substantial effect of nanotechnology on the growth of smart cities is investigated in this study. There's talk of how nanomaterials, nanosensors, and nanodevices are changing everything from energy management and environmental monitoring to transportation and healthcare in metropolitan areas. Self-healing materials, ultra-efficient energy systems, and real-time monitoring networks are all made possible by nanotechnology's ability to enable exact control at the nanoscale. The combination of nanotechnology with internet of things also promotes data-driven decision-making and the efficient use of municipal resources. The study explores the potential benefits of deploying nanotechnology in smart cities, but also the ethical, regulatory, and safety concerns that must be considered. The success of the microgrid model in many cities is due in large part to the widespread adoption and use of numerous technologies. Several impediments prevent it from expanding to the projected size. These gaps and needs can be filled by a smart nano-grid. Examining the development of nano and microgrids, alternative energy storage technologies, energy applications, and smart gadgets in smart cities, this article demonstrates the worth of nano-grids in the launch of smart cities.

Keywords

Nanotechnology, Development, Smart cities, Microgrids, Environmental

Introduction

The smart grid idea has evolved as the structural link between the legacy power grid and the new power grid architecture. Many unexpected difficulties surfaced during smart grid installation as the industry made the transition to cutting-edge technologies. Protocols, demand-side administration, security, and self-control of the overall systems are just some of the difficulties. The following are some approaches suggested for overcoming these difficulties: (a) Better network security can be implemented with the help of ultra-low-power wireless sensor networks that are linked to smart buildings, (b) Deployment of a centralized system to collect information from sensors and use it to keep tabs on the whole system, (c) The proliferation of grid convergence security issues across the world in recent days has prompted the introduction of power line communication, and (d) The incorporation of several wireless protocols (One Net, ZigBee, etc.) into smart grid systems to manage real-time processes.

The conventional grid's one-way power flow makes it difficult to apply smart

grid energy control. This also illustrates some of the challenges inherent in upgrading the existing network to a smart grid. This also marked the beginning of the rollout of certain smart devices, such as Advances Metering Infrastructure, which makes it possible for conventional meters to be smarter. This gives the consumer access to an energy consumption-based electronic billing system. Customers are becoming curious about the energy management system as a result of this. This Advances Metering Infrastructure requires a HAN or LAN to communicate with smart home equipment. In both residential and commercial settings, HAN may connect all appliances, automobiles, and storage spaces. Problems encountered during smart appliances' grid adoption are hoped to be solved by employing various modeling methodologies. Read about demand-side control behavior and various optimization techniques. The command of the demand side must be determined explicitly by the actual communication between customers and the central power provider. The practical implementation of smart grids is made possible by demand response.

Another first for last-mile connectivity has been the introduction of the distributed generations network, which will connect renewable energy sources to conventional transmission lines as part of the expanding sustainable power network. Flywheels, fuel cells, supercapacitors, hydrogen storage, etc. have been developed as energy storage options to be integrated with distributed generations for efficient and secure power utilization. Microgrids, which use clean energy from sources like the sun, wind, biomass, etc., are connected to the main grid at a point of specific coupling. Generation efficiency from solar and wind sources is time dependent. Modern energy storages lend a hand in stabilizing the entire microgrid system by offsetting these time-dependent sources. Privacy concerns, power theft, and threats to consumer safety are just some of the many security concerns that arise with MG and SG deployment. A comprehensive protection system needs to be built to prevent the security risks.

Nanotechnology's emergence

Nanotechnology is a rapidly growing science concerned with the manipulation and control of matter on the nanoscale (the range of one to a few hundred nanometers). Materials' physical, chemical, and biological properties can vary significantly from their macroscopic equivalents, but only at this scale. Nanotechnology has many potential uses, but its influence on the future of smart cities is particularly exciting. The fundamental units of nanotechnology are the sizes of individual molecules and atoms. Scientists and engineers may now manipulate material properties in new ways, allowing them to create buildings with custom-tailored features. The observed nanoscale phenomena also necessitate an interdisciplinary approach due to the blurring of established scientific fields.

Science, technology, engineering, and medicine all come together in nanotechnology. Properties that break with classical physics are what bring physics into play at the nanoscale, where quantum effects predominate. Surface contacts and molecular structures play crucial roles in the complex interactions between atoms and molecules, making a thorough understanding of chemistry essential. In addition, engineering principles are essential for making use of these exceptional qualities in real-world contexts. Synthesizing, manipulating, and integrating nanomaterials into devices and systems is necessary for them to perform their intended tasks.

Smart cities and nanotechnology

There is great potential for nanotechnology to be a game-changing tool in the effort to improve urban infrastructure and services through its incorporation into the design of "smart cities." Nanotechnology provides novel solutions that are set to revolutionize the way city's function and change in response to the complex difficulties posed by rising urbanization. Improvements to urban infrastructure and services thanks to nanotechnology's ability to create materials and systems with remarkable accuracy, efficiency, and adaptability, the field is gaining increasing relevance. This paves the way for the development of adaptive, self-repairing, and responsive "smart materials". Self-healing concrete embedded with nanoparticles, for example, can increase the durability of essential infrastructure and delay the onset of costly fissures. Similarly, nanoparticle-infused smart coatings can defend against pollutants, corrosion, and weathering, allowing structures and vehicles to last longer.

Nanotechnology's miniaturization has made it possible to design sensors and gadgets small enough to be easily embedded in urban settings, allowing for continuous monitoring and data collecting. Insights regarding air and water quality, traffic movement, energy consumption, and other variables can be gleaned via nanoscale sensors. Using this data-driven strategy, city planners and officials may better allocate funds, cut down on energy use, and enhance local services. Congestion, energy use, waste management, and environmental deterioration are just a few of the many issues that cities must face as urbanization increases. When it comes to offering scalable and long-lasting solutions, conventional methods frequently fall short. By making previously impossible breakthroughs possible, nanotechnology provides a way to take on these challenges.

Review of Literature

Fertility rates, death rates, urbanization, and international migration are the four main demographic trends that Goldstone [1] addresses in this article. He looks at the connections between these movements and their prospective effects on political, economic, and social structures. The essay discusses the risks and benefits that these tendencies present for nations and areas all over the world, and it stresses the importance of comprehensive policy responses to these developments.

Bloom [2] discusses the effects of a worldwide population of seven billion on development, infrastructure, and social stability. He delves into topics like changing birth rates and the aging of people worldwide. The author stresses the significance of addressing population expansion in the context of sustainable development, noting that, depending on the level of social adaptation, there may be both positive and bad results.

Anttiroiko et al. [3] understanding smart cities within the framework of the new service economy is the focus of this article. The writers look at how smart city infrastructure is developed on platforms that make it easier to provide citizens with

smart services. The importance of technology, data, and teamwork in developing adaptive and flexible cities is discussed. The essay also discusses the governance, privacy, and inclusion issues that arise with smart city development.

Gautam et al. [4] the problems encountered by smaller sewage treatment plants in India are the topic of this research. To enhance sanitation and lower environmental pollution costs, the authors propose a new treatment technology. The findings stress the need for treatment strategies that are both efficient and sustainable and can be adapted to local conditions.

Studying the long-term viability of aerobic and anaerobic wastewater treatment methods in a subtropical climate, Dhoble and Ahmed [5] draw some interesting conclusions. Treatment efficacy, energy use, and environmental effects are just some of the metrics put to the test. Considering issues like resource availability and energy demands, the authors stress the importance of tailoring wastewater treatment systems to a given region's environment and conditions.

What Impact do You Anticipate Nanotechnology Having on the Advancement of Smart Cities?

It is commonly anticipated that, in light of recent advances in both science and society, smart cities would undergo significant expansion in order to support a greater variety of processes and a larger metropolitan population. Many urban functions are being automated to improve efficiency and quality of life as cities develop. The impact of nanotechnology on many facets of city life is now well underway, and all indications are that this trend will only accelerate in the years ahead. Manipulating and making use of materials and structures on the nanoscale, often at sizes of less than 100 nm, is at the heart of nanotechnology. The capability of this technology to create materials at such a microscopic level has unlocked exciting new possibilities for altering the built environment. Nanotechnology is expected to have a significant effect on the construction industry. The use of enhanced construction materials with nanomaterial additions is currently being researched, with the hope that buildings and transportation systems will benefit from increased durability, flexibility, and resilience. The extraordinary self-cleaning abilities and greater resistance to weathering and corrosion that nanocoating's can give surfaces contribute to the preservation of urban beauty.

Nanotechnology has enormous potential to improve the energy industry. Utilizing cutting-edge nanomaterials, solar panels can more efficiently absorb sunlight and transform it into usable electricity. There is potential for significant energy savings thanks to the incorporation of nanoscale sensors into urban infrastructure, which would allow for real-time monitoring and optimization of energy usage in buildings and even the power grid. Water management is another issue that plagues cities. Water purification and desalination nanofillers, for example, are one example of how nanotechnology might help solve problems associated with water scarcity and poor quality. Nanosensors can be used to monitor water supplies for harmful substances like bacteria and viruses. Information and data must be able to move freely throughout a city for it to be considered "smart". Here, nanotechnology helps by allowing the creation of minuscule sensors and devices that may be embedded in city infrastructure to collect and transmit data. With this data, we can better manage traffic, optimize garbage pickup, and keep an eye on the environment in real time. Nanotechnology has the potential to revolutionize urban health and safety as well. Air pollution is a major health danger, but it can be reduced with the help of nanomaterials because of their ability to trap airborne pollutants. In addition, smart nanosensors could be used to identify harmful compounds and pathogens in the air at an early stage, improving public health efforts. However, there are obstacles to overcome in the implementation of nanotechnology in smart cities. Data privacy and security ethics require vigilant administration. Furthermore, to guarantee sustainable urban growth, it is necessary to evaluate the effects of the production and disposal of nanomaterials on the environment.

Enhancement of existing cities

Using technological, infrastructural, and social improvements, the augmentation of existing cities aims to improve metropolitan regions in their entirety. Population growth, resource scarcity, environmental sustainability, and quality of life are only some of the issues that this strategy intends to tackle in urban areas. Instead of starting from scratch, investing in already existing urban areas might result in less waste of materials and a smaller carbon footprint. Some essentials of urban renewal are as follows:

- Existing cities frequently have obsolete infrastructure that might impede their growth and efficiency, which is why it is important to upgrade and modernize these areas. Efforts to improve include fixing up infrastructure like roads, bridges, and power lines. Improve mobility and decrease congestion with the use of smart technology including advanced traffic management systems, real-time data collection, and energy-efficient lighting.
- Digitalization and the use of smart technologies can have far-reaching effects on city life. The internet of things enables real-time monitoring and management of many city-wide systems, from garbage collection to power grids. This data-driven strategy has the potential to boost productivity, cut costs, and increase services for locals.
- Adopting environmentally responsible building practices is a common method of improving urban areas. Green roofs and high-performance insulation are only two examples of how this is accomplished in the architectural design process. Renewable energy sources, such as solar panels, can be integrated into a system to help lower carbon emissions and energy use.
- Promoting mixed-use development, in which residential, commercial, and recreational spaces are merged, is a common strategy used in urban revitalization projects. This method facilitates thriving, interconnected communities while decreasing the need for lengthy journeys.

- Green infrastructure and public parks are an important part of making cities better places to live. These areas are important to the well-being of locals since they offer residents places to relax and play while also boosting air quality. Permeable roads and urban gardens are examples of green infrastructure that can reduce flood damage and strengthen the resilience of cities.

Smart cities

All cities today are rapidly evolving into "smart cities", yet the term "smart living" more accurately describes the current situation. Most urban areas are already making use of cutting-edge technologies to improve residents' standard of living. The internet of things, large databases, and machine learning algorithms all contribute significantly to improving the current infrastructure and paving the way for future technological advancements (Figure 1).

Revolution of industrial processes

All the smart networks come together, and then the data is merged and sent to the 4th industrial revolution, but first, there needs to be a good structure through which the variations may take place. The cities' reliance on these systems means that they are constantly being run to improve commercialization and understanding of how and why particular technologies should be upgraded. This is because they have the potential to revolutionize a wide variety of industrial operations.

Advanced monitoring

Other elements and facets that contribute significantly to smart cities include considerably more sophisticated kinds of monitoring that typically occur in relation to the structural health of buildings and an efficient network of transportation that circulates across cities. However, the usage of sensors is the most significant aspect that influences smart cities. These variables are utilized to support the protection of cities in terms of the economy and ecology. Sensors are required for localizing the data points, and the internet is then used for transmission across vast distances as well.

Millimeter-wave technology

NASA engineers selected the development of nano-enabled millimeters wave technology for the efficient transformation of data utilising 5G. This makes it possible for data to be transmitted effectively across radio waves and shields our cities from any interruption or disruption. Before this, it appeared like an unworkable idea to dig up a new fiber cable every few years in order to carry out the same operation. However, nanotechnology makes the use of millimeter-wave technology effective through the construction of a virtual fiber network as it successfully and uninterruptedly transmits endless amounts of data. Given that this is the quickest and most efficient method of data transmission, this represents a significant step towards the creation of smart cities (Figure 2).

Incorporation of engineering and software

Although it is obvious that engineering and software integration make all the current activities in smart cities "smart", accurate data is still crucial. The major items that contain

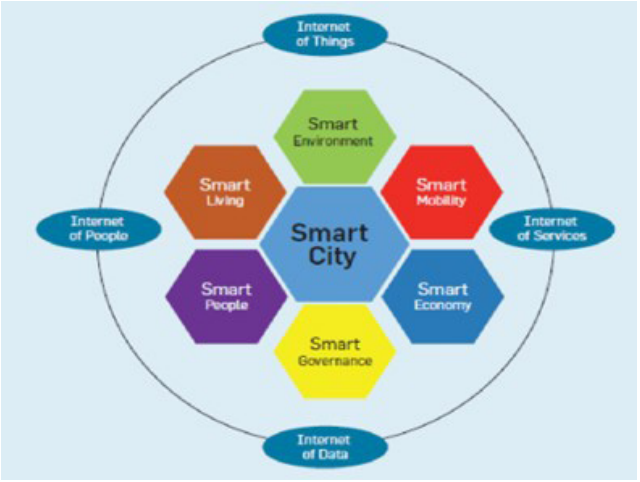


Figure 1: Smart cities.



Figure 2: Future millimeter wave applications.

nanomaterials are sensors, which are essential in the creation of smart cities. Furthermore, nanotechnology is helping to make cities smarter without requiring significant changes to the previously functional infrastructures, which is necessary for the software programmers that are used in this context to function properly.

Importance of Implementing Nano-grid to Smart Cities

Numerous concepts and traits pertaining to the smart city idea were examined. The goal of smart cities will be to change citizens from consumers to prosumers by utilizing information and communication technology to upgrade the electrical grid. The load chart shown is based on average demand, peak demand, and off-peak demand, which indicates the area's maximum power at a specific time. compared the various load characteristics of various sectors over various time periods. For instance, as compared to holiday load profiles, the load profiles of industrial and commercial buildings may vary during working days. The case study of real-time data gathered from institutions including schools, banks, homes, lighting, restaurants, etc. served as this paper's conclusion. To avoid purchasing electricity on a large scale from the power market. Because the maximum demand varies depending on the place, we can

purchase electricity. Data collected from consumers guarantees living conditions are equitable, which satisfies one of the key tenets of the smart city idea (Figure 3).

A smart city's goal is to create smart infrastructure by efficiently using science and technology for environmental resources. This covers e-governance, transportation, health care, security systems, waste management, and more. Smart power must be implemented in smart cities to increase citizen responsibility and foster a sustainable environment. Here are some examples of why using nano-grids in smart cities is important (Table 1).

- Today's blackouts and brownouts are a result of the conventional grid's inability to supply the city's energy needs. Therefore, smart power generation, transmission, and distribution are required to provide power continuously.
- To optimize the power consumption of the Smart City, data usage of individuals or businesses is automatically collected to the cloud, making citizens more responsible for energy management and able to control their own power consumption.
- It also promotes grid-integrated or grid-independent contemporary renewable energy sources. With contemporary energy storage, the freestanding grid is transformed into a new user-friendly technology.
- Predictive management of excessive power consumption and wasting energy aids in energy conservation and can be saved for later use.
- By incorporating this Nano grid technology into every residence, an automatic bill for the precise amount of electricity used may be calculated. Therefore, smart meters can take the position of manual labor, making the system even more dependable and efficient.
- With the aid of this Nano grid technology and Smart Cities, last-mile connectivity in rural areas can be easily accomplished.
- By selling or sharing the excess power to the main grid or the individual customer at a fixed price, prosumers can develop their financial advantages.

Government Policies on Smart Cities

In recent days, the Indian government has taken a number of actions to support smart power for smart cities. Here are a few recent stories with a specific focus on sustainable environ-

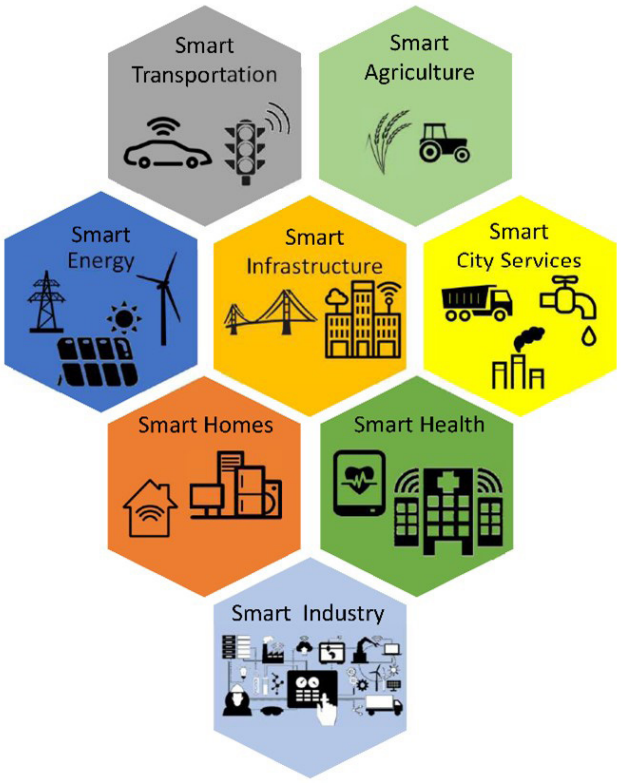


Figure 3: The significance of integrating nano-grids into smart cities.

Table 1: Essential dimensions of smart city advancement and corresponding explanations.

Aspects	Description
Smart city concepts and traits	Extensive exploration of smart city concepts and attributes.
Goal of smart cities	Transition citizens from consumers to prosumers using information and communication technology to upgrade the electrical grid.
Load chart analysis	Analysis based on average, peak, and off-peak demand, indicating the maximum power consumption during specific time frames.
Load characteristics comparison	Comparison of load profiles across sectors and time periods. Industrial and commercial buildings' profiles differ from holiday periods to working days.
Real-time data case study	Utilized real-time data from institutions (schools, banks, homes, etc.) to support conclusions.
Managing electricity demand	Aim to reduce large-scale electricity purchasing from the power market by adjusting maximum demand based on location.
Equitable living conditions	Data collection from consumers ensures equitable living conditions, aligning with smart city principles.
Creating smart infrastructure	Utilizing science and technology for efficient use of environmental resources, covering governance, transportation, healthcare, security, waste management, and more.
Implementation of smart power	Necessary to increase citizen responsibility and foster a sustainable environment within smart cities.
Importance of nano-grids in smart cities	Nano grids hold importance due to various reasons, fostering sustainability and efficient resource usage within smart urban environments.

mental practices and smart electricity infrastructure. The central ministries confirmed in budget 2020 that all power meters in our nation will be converted to smart meters over the next three years so that customers may simply choose the service providers and pay their bills. More than 1,500 electric vehicles have been registered under the National Electricity Mobility Program, which guarantees that 68 public charging stations will be in major cities like Hyderabad, Chennai, Jaipur, Ahmedabad, etc. The implementation of the solar streetlight project for rural areas by the Tamil Nadu Energy Development Agency, also encourages the installation of rooftop solar by providing subsidies. The following are some of the important topics mentioned in India 2020's Energy Policy:

- Using innovative technology, such as smart irrigation, climate-dependent agriculture, and waste management, to promote entrepreneurship and increase employment creation in the agricultural sector.
- With the advancement of renewable energies in the worldwide supply, energy security is given importance in Energy Policy 2020.
- To encourage the use of EVs, a new program called FAME (Faster Adoption and Manufacturing of Electric Vehicles) was introduced.
- According to the IEA, India's energy demand will quadruple from its current level by 2040, necessitating an emphasis on energy storage and readily available energy.
- The Smart Cities Mission seeks to improve infrastructure, reduce energy use, and more in 100 additional cities throughout the nation.
- It also seeks to replace energy-saving street lighting and pumps to produce carbon-free, sustainable electricity [6-13].

Conclusion

The notion of nano-grids and the distinctions between nano grids and smart grids were discussed in the article. Additionally, it confirms the significance of nano grids for the implementation of smart cities. This outlines the issues with the hardware and software that are related to integrating nano grids with smart cities. It will take time for the conventional grid to transform into a smart grid with strong control mechanisms. However, if effectively implemented, the nano-cloud grid's two-way communication offers various controls and makes everyone accountable. It also made clear that the state and the central government are putting up several policies and initiatives to improve our nation's future use of dependable and renewable energy. In conclusion, the use of nanotechnology is a game-changing factor in the creation of smart cities, providing benefits in a variety of areas. The amazing capacity to control materials at the nanoscale has made it possible to develop creative fixes that improve urban surroundings in previously unheard-of ways.

The impact of nanotechnology can be seen in many fields that are important for the growth of smart cities. Infrastructure is becoming more resilient and sustainable, from the use of nanocoating for self-cleaning and corrosion resistance to the advancement of construction materials with enhanced durability and resilience. This results in urban constructions that are more aesthetically beautiful, survive longer, and can withstand environmental hazards.

Acknowledgements

None.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Goldstone JA. 2010. The new population bomb: the four megatrends that will change the world. *Foreign Aff* 89: 31-43.
2. Bloom DE. 2011. 7 billion and counting. *Science* 333(6042): 562-569. https://doi.org/10.1126/science.1209290
3. Anttiroiko AV, Valkama P, Bailey SJ. 2014. Smart cities in the new service economy: building platforms for smart services. *AI Soc* 29: 323-334. https://doi.org/10.1007/s00146-013-0464-0
4. Gautam S, Ahmed S, Dhingra A, Fatima Z. 2017. Cost-effective treatment technology for small size sewage treatment plants in India. *J Sci Ind Res* 76(4): 249-254. http://nopr.niscpr.res.in/handle/123456789/41040
5. Dhoble YN, Ahmed S. 2018. Sustainability of wastewater treatment in subtropical region: aerobic vs anaerobic process. *Int J Eng Res Dev* 14(1): 51-66.
6. Mohsenian-Rad AH, Wong VW, Jatskevich J, Schober R, Leon-Garcia A. 2010. Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid. *IEEE Trans Smart Grid* 1(3): 320-331. https://doi.org/10.1109/TSG.2010.2089069
7. Zamora R, Srivastava AK. 2010. Controls for microgrids with storage: review, challenges, and research needs. *Renew Sust Energ Rev* 14(7): 2009-2018. https://doi.org/10.1016/j.rser.2010.03.019
8. Olivares DE, Cañizares CA, Kazerani M. 2011. A centralized optimal energy management system for microgrids. In IEEE Power and Energy Society General Meeting, Detroit, MI, USA.
9. Fang X, Misra S, Yang D. 2011. Smart grid—the new and improved power grid: s survey. *IEEE Commun Surv Tutor* 14(4): 944-980. https://doi.org/10.1109/SURV.2011.101911.00087
10. Burmester D, Rayudu R, Seah W, Akinyele D. 2017. A review of nanogrid topologies and technologies. *Renew Sust Energ Rev* 67: 760-775. https://doi.org/10.1016/j.rser.2016.09.073
11. Cairoli P, Kondratiev I, Dougal RA. 2011. Controlled power sequencing for fault protection in DC nanogrids. In International Conference on Clean Electrical Power, Ischia, Italy.
12. Mira MC, Zhang Z, Knott A, Andersen MA. 2015. Power flow control of a dual-input interleaved buck/boost converter with galvanic isolation for renewable energy systems. In IEEE Applied Power Electronics Conference and Exposition, Charlotte, NC, USA.
13. Dagdougui H, Sacile R. 2013. Decentralized control of the power flows in a network of smart microgrids modeled as a team of cooperative agents. *IEEE Trans Control Syst Technol* 22(2): 510-519. https://doi.org/10.1109/TCST.2013.2261071