ARDUINO IOT FUNCTIONS IN THE SMART POWER GRID SYSTEM

Vehebi Sofiu[1]
[1]UBT- University for Busines and Technology, Faculty of Energy, Pristina
e-mail: vehebi.sofiu@ubt.uni.net

Scientific article
https://doi.org/10.58952/nit20241202050
UDK/UDC 004.1:621.31

Abstract

The purpose of this study is to evaluate the IoT function of Arduino within the framework of the Smart Grid system in the electric power grid. A major advantage of this function is the automatic connection of the entire energy infrastructure in the transition period to the smart grid, which integrates technologies to increase the efficiency and management of the electric grid. There are several options for monitoring, controlling and sophisticated automation of traditional energy generation operations with the Arduino system, an open hardware and software platform. Identification of Arduino functions related to the collection of sensor data for temperature, voltage, energy consumption, and other relevant variables will be the main focus of this study. Benefits and disadvantages of automation and control of electric grid devices with Arduino and the integrated grid with renewable energy. The findings of the study will help in understanding the potential and integrity issues of Arduino in the electrical industry. They will provide recommendations for its successful future implementation in this sustainable environment.

Keywords: *IoT Function, Energy Transition, Grid Integration, Energy Conservation, Sustainable Development.*

1 INTRODUCTION

The demand for electricity in Kosovo is increasing dramatically due to technological developments that have swept the globe. Traditional fossil-fired energy has made it difficult to integrate with the automation system and its distribution. Numerous studies by several authors have shown variants of optimal solutions for different energy sources, including software ideas and proposals (Dasic et al., 2008, 2011, Damnjanovic et al., 2010, Serifi et al., 2010, Sofiu et al., 2011).

Due to this growing demand and the qualifying transition to sustainable development, the impact of computer networks on the design of the SMART automation network is becoming more complex due to the need to increase security, efficiency, and reliability and consider environmental and energy sustainability issues (Sofiu. V, 2017). These characteristics of an electrical grid led to its ultimate intelligence, which is now called the "Smart Grid". This is a conceptual approach that includes all intelligent elements to make the electrical distribution system more stable, reliable and efficient. An overview of "smart grids", including their features and the different effects on the electricity distribution business with qualifying traditional energy approaches, is given in this paper (Chibuike Peter Ohanu, Salihu Ahmed Rufai, Ugbe Christiana Oluchi, 2024). An advanced system of generation network connections for all types of generation with the automatic system increases communication reliability and significantly improves the service and quality of electricity consumption. The intelligent network with wireless infrastructure that regulates and improves the frequency infrastructure of networks with a common connection to the electricity distribution network with the Smart Grid system (Zahoor Hussain, 2016). The efficiency, security and sustainability of the power grid are enhanced by the sophisticated and controllable environment that is created when information and communication technology is integrated with the conventional power system. This idea encompasses everything from the generation and distribution of electricity to the end user, including automation, real-time monitoring and the use of renewable resources (Chen, Z., Amani, A. M., Yu, X., & Jalili, M, 2023). Information and communication technology combined with the conventional power grid produces a sophisticated and controllable environment that increases the stability, security and efficiency of the grid. This idea encompasses everything from the generation and distribution of electricity to the end user, including automation, real-time monitoring and the use of renewable energy sources (Madani Abdu Alomar, 2023). A smart grid that connects state-of-the-art networks with various industrial processes can be considered an energy ecosystem that improves energy management in a smart and effective way. A network with smart grid intersections can create an integrated network that uses comprehensive data to monitor and manage the electrical grid using modern devices and technologies connected to the Internet of Things (IoT) (Sunawar khan, Tehseen Mazhar, Tariq Shahzad, Muhammad Amir khan, Ateeq Ur Rehman, Habib Hamam, 2024). Arduino is an open hardware and software platform with a broad and sophisticated architecture that enables the electrical grid system to function with the Smart Grid network system. Accurate real-time communication, automation of the operation process and the use of artificial intelligence are key factors to improve the operation of the electrical system in just a few steps using the applications that Arduino offers for the development of devices and technology related to the Internet of Things (IoT) (Monk, Simon, 2016). Through this research work, we hope to advance knowledge about the application of Arduino to Smart Grid system problems and its potential application in building a smart and sustainable electricity grid of the future (Pradeep K. Khatua, Vigna K.Ramachandaramurthy, Padmanathan

Kasinathan, Jia Ying Yong, Jaga, 2020). A recent and comprehensive advancement in electrical infrastructure, the Smart Grid system seeks to increase the sustainability, security and efficiency of the grid through the use of information and technology. The Smart Grid creates an integrated and interconnected grid using information and communication technology, in contrast to the conventional electrical grid (Schmidt, 2015). Process automation, energy management systems, internet-connected sensors and devices, and the use of renewable resources are all essential components of a Smart Grid system. One of the key features is the capacity for sophisticated real-time grid monitoring and control, which enables grid operators to act quickly and adapt to the demands of today's energy producers and consumers (Tanveer Ahmad, Dongdong Zhang, 2021`). Global technological advances such as the Internet of Things (IoT) offer a wide range of applications in the energy sector, such as transmission and distribution, power supply, power generation, renewable energy integration, demand-side management, and environmentally sustainable development (Kabeyi, M. J. B., & Olanrewaju, O. A, 2023). To ensure the efficiency of the electricity grid with communication capabilities with all possible generations, including the characteristics of the generations with the IoT system, a fair approach is required to seamlessly integrate renewable energy sources with traditional energy and to achieve sustainable development with the smart grid (Muhammad Khalid, 2025).

2 RESEARCH METHODOLOGY

Arduino is an open hardware and software platform that has significant potential to enhance the functioning of the Smart Grid system in various ways. Utilizing Arduino in this context offers a wide range of possibilities for monitoring, automation, and efficient control of the electrical grid. This research focuses on the current landscape of traditional energy generation and the impact of renewable energy generation, emphasizing the role of Arduino in the smart grid, which includes: - Sensors and data collection - Process automation - Real-time monitoring and reliable information - Utilization of electric machines - Safety and risk management - Interaction with consumers Generation flexibility is a crucial aspect of communication within the electricity sector, allowing for an increase in the share of renewable energy capacities. In recent years, the percentage of renewable energy sources (RES) in Kosovo's energy mix has seen a modest increase. According to European directives, Kosovo has achieved a strategic objective of 25% participation in RES, in line with the goals set in its energy strategy. However, there are significant disparities in how RES are utilized across different industries, with uneven integration of various RES technologies. Therefore, efforts are underway to seek the integration of the SMART market, ensuring that the digital approach is harmonized in real time. Arduino devices can facilitate automatic communication with wireless access for information collection. Multiple sensors, capable of tracking network conditions such as voltage, energy consumption, temperature, and other relevant data, can be connected to an Arduino. The collection and interpretation of real-time data from these Arduino devices enable an accurate assessment of network performance (Schmidt, 2015). Process of automation Arduino provides the capability to develop applications for process automation. Its advanced power management features allow Arduino to control and communicate with devices on the network through specific programming. By efficiently allocating resources and optimizing their usage, automation can lead to a significant reduction in energy consumption.

With Arduino, it is possible to build a continuous real-time monitoring system for the power grid, complete with robust data collection and real-time oversight. This facilitates the rapid identification of issues and the optimization of operational processes. Additionally, Arduino's ability to store data and interface with other platforms enables the creation of a consistent and permanent archive, which can be utilized to analyze the long-term performance of the grid (Um-e-Habiba, Ijaz Ahmed, Mohammed Alqahtani, Muhammad Asif, Muhammad Khalid, 2024). Arduino can be connected to general energy systems, like wind turbines and solar panels, promoting the use of sustainable energy. This not only reduces dependence on conventional sources but also enhances the adoption of renewable energy. When integrating Arduino into a smart grid system, it's essential to develop security and risk management techniques to safeguard the system against potential threats and issues. The integrated security systems within Arduino enable real-time risk identification and mitigation. Additionally, Arduino can facilitate consumer interaction with the electrical grid by creating applications that allow users to monitor energy costs, track incentives for efficient energy use, and provide options for managing their energy consumption. This empowers users to make informed decisions regarding their energy usage while promoting overall efficiency in the grid (Sajad Ahmad Wani and Krishna Tomar, 2022). The connectivity and communication capabilities of Arduino can be smoothly integrated with various Internet of Things (IoT) devices, creating a comprehensive ecosystem that enhances the monitoring and management of the electrical grid. With real-time data tracking, both users and grid operators can quickly respond to unexpected changes and make informed decisions. This functionality allows for effective energy efficiency management by evaluating and improving energy use. Renewable energy technologies, such as wind turbines and solar panels, can be interconnected to promote the utilization of sustainable energy sources. It is essential to develop robust security and risk management strategies to protect the Smart Grid system from potential threats, and Arduino plays a crucial role in this effort. By leveraging its features to identify and address security threats swiftly, the overall security of the grid is strengthened. Additionally, applications designed with Arduino can empower users to track and manage their energy consumption effectively. These tools not only enhance energy efficiency but also raise awareness by providing personalized options and fostering direct communication with customers (Sajad Ahmad Wani and Krishna Tomar, 2022).

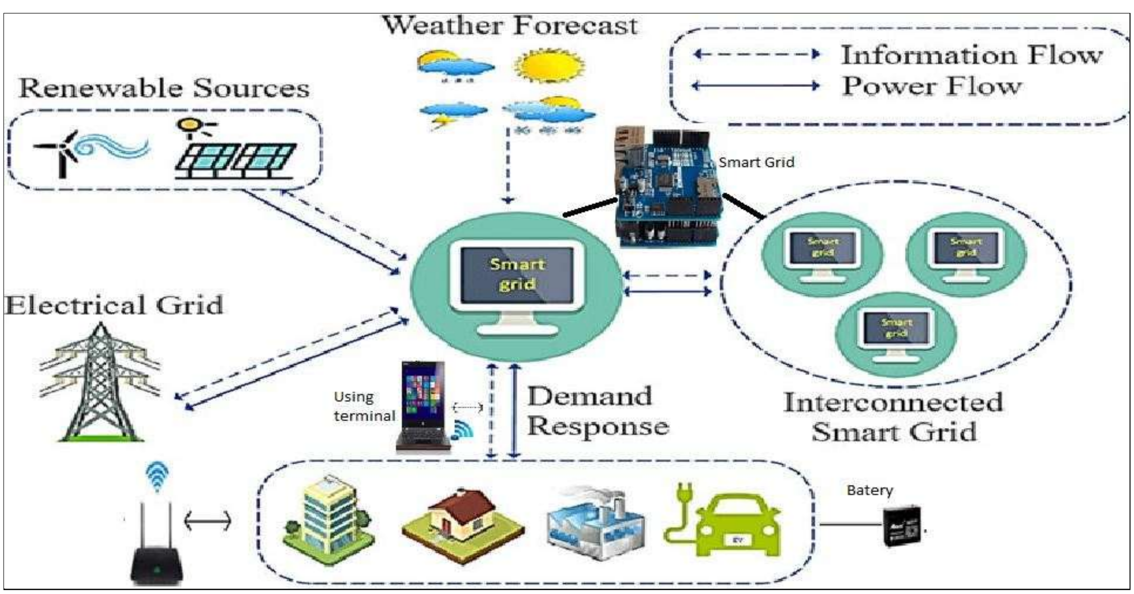

Figure 1 Managing the energy network through a smart energy system

Arduino can be effectively utilized for real-time energy monitoring and control in Smart Grid systems by incorporating several essential components and features. To gather various energy-related data, Arduino can be connected to different sensors, such as temperature, voltage, and current sensors. These sensors are connected to the Arduino's ports and pins to provide comprehensive data on the network's performance. For control purposes, devices and actuators can be connected to Arduino to manage processes within the network. When a quick response is necessary to adjust network operations, these devices activate. For instance, relays can be employed as control devices to communicate with other equipment, allowing for the isolation of specific segments of the network during emergencies. Additionally, Arduino facilitates communication with other platforms, including computers, mobile devices, and other systems connected to the Internet of Things (IoT). Through various communication protocols such as Wi-Fi, Bluetooth, and network connections, users can remotely monitor and control their energy usage. Furthermore, applications designed with Arduino empower users to effectively track and manage their energy consumption. These tools not only enhance energy efficiency but also increase awareness by offering personalized options and fostering direct communication with customers (Witt, Peter, 2016). Automatic load balancing: An artificial intelligence system can be created with Arduino to identify times when energy consumption is highest and optimize its distribution. Automatic control systems programmed with Arduino are able to respond to changes in energy usage and make adjustments in real time to maintain grid efficiency. Renewable resource monitoring: Solar and wind power generation are two examples of renewable resources whose performance can be tracked using Arduino. Depending on the availability of renewable resources, this data can be used to communicate with the grid and modify energy distribution (Monk, Simon, 2016). Automatic Load Balancing: An artificial intelligence system can be created with Arduino to identify times when energy consumption is highest and optimize its distribution. Automatic control systems programmed with Arduino are able to respond to changes in energy usage and make adjustments in real time to maintain grid efficiency. Renewable Resource Monitoring: Solar and wind power generation are two examples of renewable resources whose performance can be tracked using Arduino. Depending on the availability of renewable resources, this data can be used to communicate with the grid and modify energy distribution (Monk, Simon, 2016). In the context of a smart grid, Arduino can be used with a variety of sensors and devices to collect data related to temperature, voltage levels, energy usage, and other relevant information. Custom sensors can be attached to the Arduino to track power usage across different segments of the network or individual devices. The purpose of voltage sensors is to keep an eye on voltage levels across the entire network. The voltage levels can be read and transmitted for further analysis using an Arduino Figure 2. By using this data to determine locations with high or low voltage, power distribution can be optimized and risk can be reduced.

Figure 2 Integrated voltage sensor

A series of temperature sensors can be attached to an Arduino to track the temperature in areas where network equipment is located. Accurate temperature readings are provided by sensors such as the DS18B20. These sensors can be used to detect hot spots, which can affect power dissipation and the performance of electrical equipment. Arduino-connected sensors and devices are critical in improving energy monitoring and management in the Smart Grid. These devices provide necessary information and enable smart decisions for the efficiency, security, and sustainability of the electrical grid.

3 DISCUTION OF RESULTS

Voltage and current sensors enable monitoring of grid load and detection of high voltage or overload locations. This data is used by Arduino to optimize power distribution, ensuring that each grid component uses energy most economically and efficiently possible. A comprehensive view of real-time energy usage is provided by energy consumption sensors. This data can be examined using Arduino to determine peak demand times and reduce energy costs and losses. Smart Grid reduces costs for both the supplier and the end user through energy efficiency management. Light and temperature sensors are essential for keeping an eye on the operation of renewable energy sources such as wind turbines and solar panels. The power adjustment and integration of these sources into the grid are coordinated by Arduino. Arduino can automate grid load control using relays, voltage and current sensors. The electronic system can intervene in the automatic approach by isolating specific segments of the network or using other techniques to manage the loads when the sensors are interrupted to detect high load points. Temperature sensors help detect emergency conditions, such as excessive temperatures or gas leaks. This technology has made it possible to create automated systems and applications for managing and monitoring energy in real-time. Scheduled automatic actions are events with specific conditions that can be created by IoT software to enable the Arduino to intervene when there is a power outage at a certain time. The Arduino connects to temperature, voltage, current and other sensors to track the state of the network in real-time. It then uses this data to automatically modify network activities. The Arduino is configured to recognize emergencies, such as sudden temperature fluctuations, high voltage or unexpected usage. To address these circumstances, the automated system can immediately intervene and isolate specific segments of the network, use different resources, or modify processes to reduce risk. The resilience and efficiency of the network can be increased by using this data for additional analysis and decision-making. By connecting to sensors for temperature, voltage, current, and other variables, the Arduino continuously assesses the state of the network and uses this data to automatically modify network operations. The Arduino is configured to recognize emergencies, such as sudden temperature fluctuations, high voltage, or unexpected usage. The automated system can immediately intervene and isolate specific segments of the network using different resources or modify processes to reduce risk. Monitoring and reporting collects, tracks, and reports a variety of network performance metrics. The resilience and efficiency of the network can be increased by using this data for additional analysis and decision-making.

CONCLUSIONS

Arduino offers significant potential for automating processes and managing devices within a smart grid system due to its high flexibility, scalability, and capacity to support a wide range of applications. One of its applications is automating load control in the grid by monitoring energy usage and responding with predefined actions. To minimize the risk of voltage drops, Arduino can be programmed to turn off non-essential devices when power demand becomes excessively high. Moreover, Arduino can facilitate the monitoring and regulation of renewable energy sources, such as wind turbines and solar panels. When the solar panel system generates a surplus of energy, Arduino can prioritize its use in the grid effectively. By connecting to sensors that measure voltage, current, and other variables, the grid's operations can be tracked in real-time, allowing for immediate reporting of any issues or irregularities. For example, if voltage levels drop in a particular area, Arduino can activate specific devices to boost voltage and stabilize the power supply. Power consumption patterns can be analyzed using Arduino, enabling adjustments in power distribution to align with current demands. Based on predicted energy needs, Arduino can effectively intervene to either increase or decrease the power supply. In terms of emergency response, Arduino can be configured to detect and respond to critical situations, such as gas leaks or voltage surges. The automated system can immediately isolate affected segments of the network, reducing risks to users and infrastructure.

References

[1] Amazon. (2023). *Robodo VOLTSENS Voltage Detection Sensor Module - Arduino, ARM and other MCU*. Retrieved from Robodo VOLTSENS Voltage Detection Sensor Module - Arduino, ARM and other MCU: https://www.amazon.in/Robodo-Electronics-VOLTSENS-Voltage-Detection/dp/B07B91C3RK

[2] Chen, Z., Amani, A. M., Yu, X., & Jalili, M. (2023). Control and Optimisation of Power Grids Using Smart Meter Data. *Sensors*, 23(4), 2118.

[3] Chhaya, L. (2018). *IoT-Based Implementation of Field Area Network Using Smart Grid Communication Infrastructure*. Retrieved from mdpi: https://www.mdpi.com/2624-6511/1/1/11

[4] Chibuike Peter Ohanu, Salihu Ahmed Rufai, Ugbe Christiana Oluchi. (2024). A comprehensive review of recent developments in smart grid through renewable energy resources integration,. *HELYON*, Volume 10, Issue 3,.

[5] Cytron. (2020). *Light Sensor Module*. Retrieved from Light Sensor Module: https://my.cytron.io/p-light-sensor-module

[6] Damnjanovic, Z.; Mancic, D.; Randjelović, D.; Dasic, P. & Serifi, V. (2010): ICT in enviromental and educations - competitive advantage in new economy. *Annals of the University of Petrosani, Electrical Engineering,* Vol. 12 (XXXIX) (2010), pp. 51-56. ISSN 1454-8518.

[7] Damnjanovic, Z.; Strbac, N.; Serifi, V. & Ranđelović, D. (2011): Information systems for environment. In: *Proceedings of XIX International Scientific and Professional Meeting ECOLOGOCAL TRUTH Eco-Ist 2011,* University of Belgrade – Tehnical Faculty Bor, Jun 01-04, 2011, s. 276-283, ISBN 987-86-80987-84-2.

[8] Dasic, P. & Serifi, V. (2008): Programming languages used for building environmental decision suport systems (EDSS). In: *Proceedings on 3rd International Conference "Quality, Management, Environment, Education, Engineering - ICQME 2008"*, Milocer, Montenegro, 09-12. September 2008. Podgorica (Montenegro): Faculty of Mechanical Engineering, 2008, pp. 271-27. ISBN 978-9940-527-03-7. Available on Web site: http://www.qme-conference.org/papers/view/29.

[9] Dasic, P.; Petropoulos, G.; Andjelkovic-Pesic M. and Serifi, V. (2010): IEnvironmental Information Systems (EIS). *In: Proceedings of the 1st Scientific and Professional Conference Risks and Eco-Safety in the Postmodern Environment Eko-DUNP 2010 with International Participation*, Novi Pazar, Serbia, June 10-12, 2010. Editor: Rade Biočanin. Novi Pazar: State University of Novi Pazar (DUNP), 2010, s. 47-60, ISBN 978-86-86893-28-4.

[10] Dasic, P.; Serifi, V. & Bulatovic, Lj. (2011): Wisdom in knowledge management strategy. In: *Proceedings of Extended Abstracts of the Annals of Session of Scientific Papers "IMT Oradea - 2011",* Oradea, Romania, 26-27. May 2011. Oradea (Romania): Editura Universităţii din Oradea, 2011, pp. 5.23. ISBN 978-606-10-0508-6. Available on Web site: http://imtuoradea.ro/auo.fmte/files-2011-v2/MANAGEMENT/Dasic%20Predrag%20L.pdf.

[11] Dasic, P.; Serifi, V. & Jecmenica, R. (2008): Methodology for building an EDSS system. *Journal IMK-14 Research & Development*, Year. XIV, br. (28-29) 1-2/2008 (2008), str. 107-118. ISSN 0354-6829.

[12] Divyanshu Sagar, Ayushya Ujjwal, Ayush K. Binu. (2022). POWER GRID CONTROL USING ARDUINO. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*.

[13] Instructables. (2021). *Simple Arduino Home Energy Meter*. Retrieved from Simple Arduino Home Energy Meter: https://www.instructables.com/Simple-Arduino-Home-Energy-Meter/

[14] Jayaweera, D., & Liyanage, K. M. . (2018). *An Arduino-Based Real-Time Monitoring and Controlling System for Grid-Connected Solar PV Systems".* Moratuwa: 2018 Moratuwa Engineering Research Conference (MERCon), Moratuwa, Sri Lanka, 255-260.

[15] Kabeyi, M. J. B., & Olanrewaju, O. A. (2023). Smart grid technologies and application in the sustainable energy transition: a review. *Sustainable Cities and Society*, 685–758.

[16] Madani Abdu Alomar. (2023). An IOT based smart grid system for advanced cooperative transmission and communication,. *https://doi.org/10.1016/j.phycom.2023.102069.*, Volume 58.

[17] Makerselectronics. (2023). *MQ-4 Gas Sensor Module*. Retrieved from MQ-4 Gas Sensor Module: https://makerselectronics.com/product/mq-4-gas-sensor-module

[18] Md Abdullah Al Rakib, Sumaiya Nazmi, Md Hasan Imam, Mohammad Nasir Uddin. (2021). Arduino Based Automatic Power Factor Control. *INTERNATIONAL JOURNAL of SMART GRID*.

[19] Monk, Simon. (2016). Programming Arduino. In S. Monk, *Programming Arduino: Getting Stardted with Sketches* (pp. 60-120). New York: McGraw-Hill Education TAB: 2nd edition.

[20] Muhammad Khalid. (2025, Januar). Smart grids and renewable energy systems: Perspectives and grid integration challenges. *Energy Strategy Reviews*, volume 51.

[21] Pradeep K. Khatua, Vigna K.Ramachandaramurthy, Padmanathan Kasinathan, Jia Ying Yong, Jaga. (2020). Application and assessment of internet of things toward the sustainability of energy systems: Challenges and issues,. *https://doi.org/10.1016/j.scs.2019.101957.*, Volume 53,.

[22] Sajad Ahmad Wani and Krishna Tomar. (2022). Smart Grid System Using IoT . *International Journal of Innovative Research in Computer Science & Technology (IJIRCST)*, 6-8.

[23] Schmidt, M. (2015). Arduino . In M. Schmidt, *Arduino: A Quick-Start Guide, Second Edition* (pp. 80-81). Pragmatic Bookshelf: 2nd edition.

[24] Serifi, V.; Curcic, S. & Dasic, P. (2010): Review of software tools for logistics support and use of alternative fuels from communal systems. *Annals of the Oradea University - Fascicle of Management and Technological Engineering*, *CD-ROM Edition,* Vol. IX (XIX), No. 3 (2010), pp. 3.179-3.188. ISSN 1583–0691. Available on Web site: http://imtuoradea.ro/auo.fmte/files-2010-v3/TCM/Serifi%20Veis%20L.pdf.

[25] Serifi, V.; Curcic, S. & Dasic, P. (2010): Review of software tools for logistics support and use of alternative fuels from communal systems. In: *Proceedings of Extended Abstracts of the Annals of Session of Scientific Papers "IMT Oradea - 2010",* Oradea, Romania, 27-29. May 2010. Oradea (Romania): Editura Universitătii din Oradea, 2010, pp. 3.98. ISBN 978-606-10-0128-6.

[26] Sofiu, V. & Serifi, V. (2011): Prizren is convenient location for solar lighting. In: *Proceedings of the 1st International Scientific and Methodological Conference "Quality of Education: management, Certification, Recognition",* Kramatorsk, Ukraine, 31. October to 02. November 2011. Edited by Sergey V. Kovalevskyy. Kramatorsk (Ukraine): Donbass State Engeniering Academy (DSEA), 2011, pp. 159-164. ISBN 978-966-379-516-4.

[27] Sofiu, V.; Serifi, V.; Dika, Z. & Abazi, A. (2011): Intensity of incidental light and solar energy potentional of the Balkan region. *Annals of the Oradea University - Fascicle of Management and Technological Engineering*, *CD-ROM edition,* Vol. X

(XX), No. 2 (2011), pp. 3.64-3.74. ISSN 1583–0691. Available on Web site: http://imtuoradea.ro/auo.fmte/files-2011-v2/MECATRONICA/Sofiu%20Vehbi%20L2.pdf.

[28] Sofiu, V.; Serifi, V.; Dika, Z. & Abazi, A. (2011): Intensity of incidental light and solar energy potentional of the Balkan region. In: *Proceedings of Extended Abstracts of the Annals of Session of Scientific Papers "IMT Oradea - 2011",* Oradea, Romania, 26-27. May 2011. Oradea (Romania): Editura Universitătii din Oradea, 2011, pp. 3.26. ISBN 978-606-10-0508-6. Available on Web site: http://imtuoradea.ro/auo.fmte/files-2011-v2/MECATRONICA/Sofiu%20Vehbi%20L2.pdf.

[29] Sofiu, V.; Serifi, V.; Dika, Z. & Krasniqi, I. (2011): Implementation of solar led lighting in Shtime. *Annals of the Oradea University - Fascicle of Management and Technological Engineering*, *CD-ROM edition,* Vol. X (XX), No. 1 (2011), pp. 3.84-3.94. ISSN 1583–0691. Available on Web site: http://imtuoradea.ro/auo.fmte/files-2011-v1/MECATRONICA/Sofiu%20Vehbi%20L1.pdf.

[30] Sofiu. V. (2017). Wind turbine technology enables sustainable development of electricity in Kosovo. *UBT International Conference*, 135-145.

[31] Subhani, M. Z., Hussain, A., & Malik, S. A. (2009). Arduino based Real-time Power Monitoring and Controlling System. In M. Z. Subhani, *2019 International Conference on Engineering and Emerging Technologies (ICEET), Lahore, Pakistan, 1-6.* (pp. 1-6). Lahore, Pakistan.

[32] Sunawar khan, Tehseen Mazhar, Tariq Shahzad, Muhammad Amir khan, Ateeq Ur Rehman, Habib Hamam. (2024). Integration of smart grid with Industry 5.0: Applications, challenges and solutions,. *https://doi.org/10.1016/j.meaene.2024.100031*, Volume 5.

[33] Tanveer Ahmad, Dongdong Zhang. (2021`). Using the internet of things in smart energy systems and networks,. *https://doi.org/10.1016/j.scs.2021.102783*, Volume 68.

[34] Um-e-Habiba, Ijaz Ahmed, Mohammed Alqahtani, Muhammad Asif, Muhammad Khalid. (2024). The role of energy management technologies for cyber resilient smart homes in sustainable urban development,. *https://doi.org/10.1016/j.esr.2024.101602.*, Volume 56.

[35] Witt, Peter. (2016). ARDUINO - Functions Reference. In P. Witt, *ARDUINO* (pp. 11-13). Tesla Institute.

[36] Zahoor Hussain. (2016). Impact of wireless communication networks on smart grid & electrical power distribution systems of electricity infrastructure. *Sci Lahore*, 28(5),4959-4964.