ANALYSIS OF DIFFERENT TYPES OF AUTOMATION WITH EMPHASIS ON SECOND-LIFE BATTERY IMPLEMENTATION

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The objective of this paper is to classify different automation systems by examining their distinguishing characteristics and highlighting a specific case applied in a photovoltaic system.

Thus, the first part present advantages and disadvantages of applying some types of automation which may vary depending on the specific industry, application, and technological advancements. Based on the analysis performed, methods and approaches can be established to achieve precision in control, stability, adaptability, cost, and maximum performance. The main objective is to enhance understanding and offer a view of the available automation choices, facilitating informed decision-making for businesses regarding the integration of automation into their operations.

In the last part of the paper, a representative case is presented, as well as the role of a fixed-type automation through the application in a system of transforming solar energy into electrical energy with its storage in a second-life vehicle battery.

Keywords: automation, classification, characteristics, second-life battery

1. Introduction

Industrial process automation is an area where technology is used to improve operational efficiency as well as productivity by reducing or even eliminating manual and/or repetitive operations, which are replaced by automated systems. This seeks to minimize human intervention in the execution of tasks and processes. Automation is a complex process that requires resources, proper planning, and technical expertise. All these can only be implemented or developed by highly trained human resources to ensure the success of the identified solution,

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along with computing equipment constantly subjected to a significant development of their performance and capacity.

The processes that take place in an organization are evaluated, manual and repetitive tasks that can be automated are identified, such as data logging processes, document management, reporting processes or any other type of activity that needs constant human intervention. Depending on the needs of the organization, a compatible process automation software platform can be chosen. The automated workflow involves configuring execution elements, such as software robots, in order to perform various tasks such as extracting data from documents, updating databases, processing information, etc. These processes can only be implemented on a large scale after careful monitoring and testing, and the automated solution to be implemented must be passed through several filters in order to verify its correct operation. If improvements are needed, they must be easily applied so that the solution originally agreed is not fundamentally degraded.

The use of industrial automation equipment can only bring benefits from the simplest processes to the most complex. From a simple coffee dispenser to the most complex assembly line of integrated boards, automation equipment ensures timely and desired quality of the final product. Electricity savings, personnel savings, increased quality and shorter production time are some aspects improved by the implementation of automated systems. If a few decades ago, an average of 100 specialized laborers worked on a vehicle for several hundred hours, now a few highly qualified people work on an automated production line, and the process takes between ten and twenty hours. As automation grows, its impact on society becomes clearer [1].

In our days, in industrial automation systems, it is sufficient to have only a few operators to control and verify the progress of processes. Taking on monotonous and physically demanding jobs, automation allows employees to focus on more creative and complex tasks, tasks that require critical thinking and problem-solving skills. This encourages a culture of innovation and continuous improvement within the organization, resulting in a more engaged workforce. With automation performing routine operations, employees can work in areas that require human reasoning, ultimately leading to job satisfaction and overall productivity. There are technological processes, such as automated bottling or assembly lines, which are fully automated, human presence being required only at the final quality control of the finished product. These aspects represent the success of a modern business compared to the business of a few decades ago. The quality through which the products are made results in obtaining larger orders, fulfilled in a much shorter time.

The Internet and development of information technology have also contributed to the technological development of automated systems. Currently, most companies dealing with the design, implementation or maintenance of automated systems offer their services online. Also, some automated processes can be tracked and controlled via the Internet from a long distance. All products that are part of the field of industrial automation can also be found on the Internet, in presentation catalogs, each with its own operating parameters and even case studies with the implementation of the respective equipment. Depending on the scale of the processes involved in the designed machine, tendering, design, or maintenance services can be offered exclusively online. The implementation of industrial automation equipment, however, remains a physical process, which must be carried out by specialized personnel at the assembly site of the test benches.

2. Types of industrial automation systems

From a simple conveyor belt in a manufacturing line to advanced machine learning systems and artificial intelligence, it is important to understand the types of industrial automation to identify the processes where each technology will find the greatest benefit. Not every solution or system will suit the application or goals set. Several types of industrial automation systems are presented:

2.1.Fixed type of automation (Hard Automation)

It is associated with the implementation of systems with fixed and limited functionality, being designed, in most cases, for a set load from the beginning, high volume production and continuous workflow. This type of industrial automation rarely undergoes changes and is characterized by repeatability, small implementation and installation time, static configuration, low costs [2]. Because the expense and time associated with the product for which it was configured are small, the tendency to be adapted for a new product is often abandoned. The expenses as well as the time allocated increase exponentially and often that solution is given up at the expense of another configured new product.

An example of fixed automation type is an automated system for distributing medicines in a hospital, which can sort and dispense medicines to patients according to their prescription. Another example is an automated document scanning and sorting system, which can automatically classify and route documents according to certain criteria [3].

2.2.Programmable automation

It offers more flexibility and adaptability compared to fixed automation type, thus enabling organizations to respond more effectively to the ever-changing demands of the business environment. This type of automation can be reprogrammed to perform different tasks or adapt to changes in workflow, without requiring manual intervention or physical changes. To guide the automated system in performing the specified tasks, automation of a programmable type is based on the use of programs and instructions. Thus, through programming, sequences of actions, logic and rules can be defined to guide the behavior of the automated system according to specific requirements.

In contrast to fixed automation type, programmable automation can also include capabilities to interact with other systems and devices, such as sensors, other machines, or computer networks. This allows the automated system to receive information from other sources and operate on them, opening more advanced possibilities for automation and control.

Examples of programmable automation include programmable industrial robots that can be reprogrammed to perform various tasks, as well as automated building control systems. Some applications have the ability to regulate temperature, humidity and air quality [4], while others can optimize energy consumption in a smart home through interfaces such as Alexa (Amazon), Google Assistant and similar platforms, managing aspects such as energy efficiency, security and entertainment [5]. In particular, the convenience of wireless systems or those that require minimal changes to existing structures make them particularly advantageous. Consequently, these solutions can be applied without problems to pre-existing buildings [5]. In addition, IoT (Internet of Things) systems play an important role in the remote control of household appliances and devices in a safe and comfortable way as shown in [6], [7]. These systems use various communication protocols, including ZigBee, Ethernet, Z-Wave, X10, and others.

2.3.Flexible type automation

It offers a higher level of agility and adaptability compared to limited fixed or programmable automation, as it uses technologies and systems that can be configured and adapted in a more dynamic and versatile way to respond to changes in processes and requirements.

Dissimilar to fixed automation type systems, flexible type systems can be adjusted and reprogrammed in a faster and more flexible way. To enable modules or components to work together in an integrated way, these systems use modular and interconnected approaches, thus facilitating the rapid exchange and replacement of modules according to current needs and conditions. Advanced technologies such as artificial intelligence, collaborative robots that can learn and adapt their behavior to interact with humans, and other emerging technologies are also used. All this allows flexible automation to adapt to changes and tackle complex and varied tasks, thus providing machine learning, adaptation, and interaction capabilities with the environment.

Examples of flexible automation include collaborative robots [8], flexible production lines that can quickly change their configuration to produce a variety of products, and intelligent transport systems that can adapt to changes in logistics flow.

2.4.Integrated automation

It refers to the use of automated systems that are fully integrated into a larger system or global workflow. This involves connecting and coordinating automated systems and devices to work together in a synergistic way, instead of being used as separate entities.

Integrated automated systems are capable of exchanging information in real time so that each automated component has access to up-to-date data and information, decisions are made in real time, and automated operations are adjusted according to requirements and changing process specifications. It relies on the use of communication and standardization technologies to facilitate the integration and interoperability of automated systems. It may include standard communication protocols, interoperability standards and the use of common networks and infrastructures. The integration of devices and machines into a single control system connects the steps between processes, production lines and more. Integrated automation is a more holistic approach to production. As IioT (Industrial Internet of Things) and Industry 4.0 advance, independent machines and production lines are able to communicate in a network to become increasingly flexible and move towards on-demand manufacturing and increased customization according studies [9], [10].

Examples of this type of automation can include fully integrated production lines, where different machines and robots work together in a continuous and synchronized workflow. Building control systems that integrate temperature, lighting and security control into a single system are an example of integrated automation. Also, implementing automation in the existing medium voltage grid of an electricity distribution operator, aiming to reduce the values of energy quality indicators can bring several benefits, such as increased efficiency, increased productivity, improved quality, and reduced costs [11]. Through proper coordination and interaction of different automated components, superior performance and long-term competitive advantage can be achieved.

3. Comparative study of the differences between fixed, programmable, flexible, and integrated automation

In order to achieve the goal of this work, we created an overview of the differences between the four types of automation. One important thing to note is that the advantages and disadvantages of each type of automation can vary depending on the specific application, industry, and technological advancements.

The criteria for this comparative study are detailed in Table 1:

Table 1

Comparative study of the differences of the four types of automation

Criteria	Fixed Automation	Programmable Automation	Integrated Automation	Flexible Automation
Control	Predetermined, hardwired	Computerized, with some manual input	Centralized, computer-controlled	Adaptable, computer-controlled, manual override
Changeover Capability	Usually difficult and time-consuming	Requires reprogramming or reconfiguration	Can be modified with some effort	Rapid and easy changes, adaptable
Applications	High-volume, repetitive	Moderate-volume, variable	Varied and specialized	Custom, variable, adaptable
Initial Investment	Low	Moderate	High	High
Customization Capability	Limited	Moderate	Extensive	High
Maintenance Requirements	Low	Moderate	Regularly scheduled maintenance	Frequent, adaptive maintenance
Human Intervention	Minimal	Minimal to moderate	Reduced but still present	Varied, frequent
Production Rate	Typical high and constant	Variable, adjustable	Variable, can be optimized	Variable, adaptable, can be optimized
Production Volume Flexibility	Low flexibility	Moderate flexibility	Moderate to high flexibility	High flexibility
Skill Requirements for Operators	Low skill required	Skilled operators	Skilled technicians and engineers	Skilled technicians and engineers
System Complexity	Simple, specialized	Moderate complexity	High complexity	Variable complexity depending on task
Downtime for Maintenance	Minimal	Moderate	Planned downtime for maintenance	Unplanned downtime may occur more often
Energy Efficiency	Variable, can be optimized	Can be optimized	Can be optimized	Can be optimized
Investment Payback Period	Shorter payback period	Moderate payback period	Longer payback period	Longer payback period
Adaptability to Market Changes	Limited adaptability	Moderate adaptability	Can adapt to market changes with effort	Highly adaptable to market changes

Product and Process Innovation	Limited innovation	Moderate innovation	Encourages innovation	Facilitates rapid innovation
Initial Configuration Time	Short setup time	Moderate setup time	Longer setup and integration time	Variable setup time
Maintenance Predictability	Predictable maintenance schedule	Predictable maintenance schedule	Variable maintenance schedule	Less predictable maintenance schedule
Complexity of Changeover	Complex and time-consuming	Moderate complexity	Variable complexity	Rapid and less complex changeovers
Adaptability to New Technologies	Limited adaptability	Moderate adaptability	Can adapt with substantial effort	Highly adaptable to new technologies
Job Redundancy	High job redundancy	Moderate job redundancy	Reduced job redundancy	Variable job redundancy
Quality Control	Consistent quality	Variable quality	Improved quality control systems	Variable quality control systems
Data Analysis and Optimization	Limited data analysis	Moderate data analysis	Advanced data analysis and optimization	Extensive data analysis and optimization
Environmental Impact	Often less efficient	Moderate efficiency	Can be optimized for efficiency	Can be optimized for efficiency
Interoperability	Limited interoperability	Moderate interoperability	Enhanced interoperability	High interoperability
Initial Training Requirements	Low training requirements	Moderate training required	Moderate training requirements	Variable training requirements
Adaptation to Regulatory Changes	Challenging to adapt	Moderate adaptation	Can adapt with effort	Highly adaptable to regulatory changes

4. Representative case of a fixed automation type system

An example of this type of automation is the control (charging/discharging) of a second-life battery (battery which was used in an electric vehicle). The recycling and reuse of electric vehicle batteries (EVB) is an essential element in reducing their environmental impact and their contribution to the energy transition [12], [13], [14]. EVB lose their storage capacity after about ten years of use in an electric vehicle and then need to be changed. It is believed that below 70% to 80% of their storage capacity, batteries are no longer efficient enough to be used on electric vehicle (ref. lithium-ion batteries). However, EVB continue to offer interesting storage capacities and can therefore still be used for other purposes, such as energy storage in a photovoltaic system [15], [16], [17]. In this regard, many innovative uses have been developed.

Such an innovative use can be represented by the management system of second-life EVB integrated into a system for converting solar energy into electricity using photovoltaic cells. The principle of operation of the proposed automated device consists in charging/discharging the second-life EVB. The elements used for the automated system are:

- an open-source electronics platform named Arduino [18];
- viewing element;
- electronic device for charging and discharging control called BMS (battery management system);
- input elements, photovoltaic panels;
- EVB.

The functionality consists in the fixed automation type of the constituent elements where, regardless of the chosen input data, the device tracks ***only*** the charging or discharge of the battery of accumulators, as follows:

- in the first phase, the Arduino controller receives, through input elements, EVB-specific data: voltage and electric current;
- EVB parameters are being watched using a viewing screen;
- the BMS monitors EVB charging and discharging processes;
- in the second phase, the controller, with the help of the BMS, manages the EVB protection system during charging and discharging processes;
- in the third phase, depending on the amount of solar energy converted by the photovoltaic panels, the controller feeds the consumers in the circuit and, at the same time, charges the EVB with the surplus energy;
- in phase four, the controller supplements the energy requirements used by the loads.

For a better understanding of the automated device, we developed a block diagram shown in Fig.1.

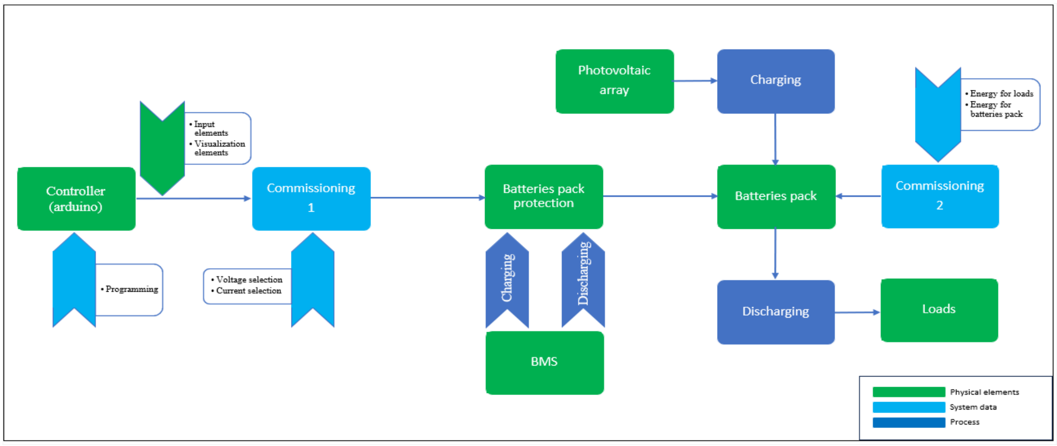

Fig. 1. Diagram of automated device

The main advantage of using EVB second-life in such a project is the way to store excess energy for use at times when access to solar energy is limited. At the same time, due to the high energy density of these types of batteries, the efficiency of the photovoltaic system is maximized by efficient charging and discharging of electricity. EVB are considered more environmentally friendly compared to other types of batteries because they produce fewer emissions and pollutants during operation, and the service life is extended throughout the battery's life, not just as long as the car considers it efficient. This aligns with the clean and sustainable energy goals of many photovoltaic system owners.

To further exemplify, we used our own 6.48 kW On-Grid residential PV system with the following components:

- 12 photovoltaic panels with the following characteristics under standard test conditions: voltage at point of maximum power - 41.64V, current at point of maximum power - 12.97A, module efficiency 20.89% [19];
- On-grid inverter with the following characteristics: DC maximum input current - 18A, DC input voltage range - 80÷1000V, AC maximum output power - 8.2kW, AC maximum output current - 35.7A [20];
- Smart meter with 100A maximum measured current [21].

A simple calculation can be made based on the data collected (Fig. 2) using the personal account from the inverter application for 172 days, during which 3,653.64 kWh of active energy were produced. Residential consumption in the same period was 1,479.58 kWh.

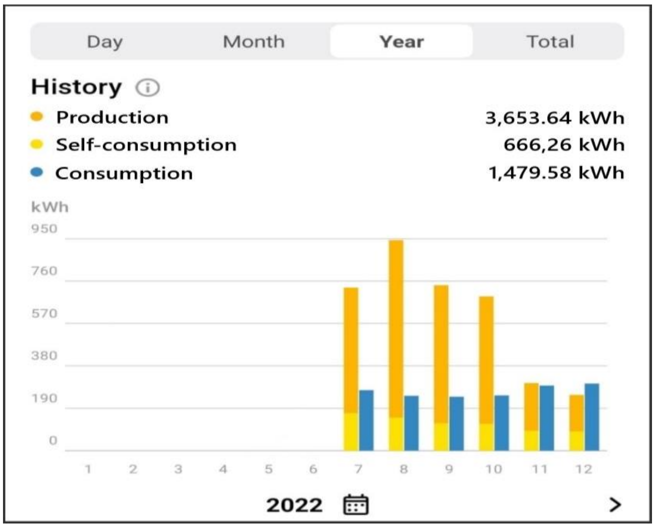

Fig. 2. Collected data during 172 days

Parameters needed for the analyze are:

- 6.48 kW maximum power capacity of the On-Grid PV system;
- 172 days of On-Grid PV system used (No_{days});

- 3,653.64 kWh energy produced by the On-Grid PV system;
- 1,479.58 kWh total energy consumed by residential housing;
- 813.65 kWh energy consumed direct from the grid ($E_{c\_total\_from\_grid}$);
- 80% hypothetical DOD (deep of discharge) of the EVB pack;
- 70% EVB SOH (state of health);
- 3 days of hypothetical energy reservation (for cloudy or winter weather) or for 7.66 kWh representing the peak of one day consumption (obtained from the data acquired during the 172 days);
- 1.30 lei → 0.2632 euro (currency/ kWh in 03.09.2023) cost of buying 1kWh from the grid ($Cost_{kWh\_from\_grid}$);
- 0.65 lei → 0.1312 euro (currency/ kWh in 03.09.2023), the average cost of selling 1 kWh to the grid.

a. EVB capacity deduction:

The daily energy consumed ($E_{c\_from\_grid/day}$) was calculated using equation (1):

$$E_{c\_from\_grid/day} = \frac{E_{c\_total\_from\_grid}}{No_{days}} = \frac{813.65}{172} = 4.73 kWh \tag{1}$$

The electric vehicle battery capacity required for three days of autonomy is $C_{\mathrm{EVB}\_for\_\mathrm{three\_days}} = 14.19 kWh$.

Considering that used EVB has SOH up to 70%, we will calculate the battery capacity ($C_{EVB70\%}$) following equation (2):

$$C_{EVB70\%} = C_{EVB\_for\_three\_days} \cdot \frac{1}{70\%} = 20.27 kWh \tag{2}$$

In order not to further degrade the battery over time, we will consider the hypothetical use of it up to 80% DOD and calculate the total capacity (C_{EVB_total}) with the following formula (3):

$$C_{EVB\_total} = C_{EVB70\%} \cdot \frac{1}{80\%} = 25.33 \cong 25.5 kWh \tag{3}$$

Thus, we managed to obtain a total battery capacity required of 25.5 kWh.

b. Money saving

The total cost of energy consumed from the network will be given by formula (4):

$$Cost_{total\_from\_grid} = E_{c\_total\_from\_grid} \cdot Cost_{kWh\_from\_grid} = 813.65 \cdot 0.2632 = 214.15 euro \tag{4}$$

But, since the same amount of the total produced by the PV system and injected into the network brought a benefit of only $813.65 \cdot 0.1312 = 106.75 euro$, a loss of $214.15 - 106.75 = 107.40 euro$ was found.

So, by using EVB in conjunction with 6.48 kW On-Grid PV, the total value of 107.40 euro represent money saving during the 172 days. But what if the calculation will be for 365 days or incoming energy value from the grid will contain a part of the energy for heat pump, electric vehicle etc.?

c. Graphical analyze of benefits using EVB

In addition to the economic benefits discussed above, the use of EVB will bring other advantages such as:

- smaller amount of energy fed into the grid avoiding overload (Fig. 3)

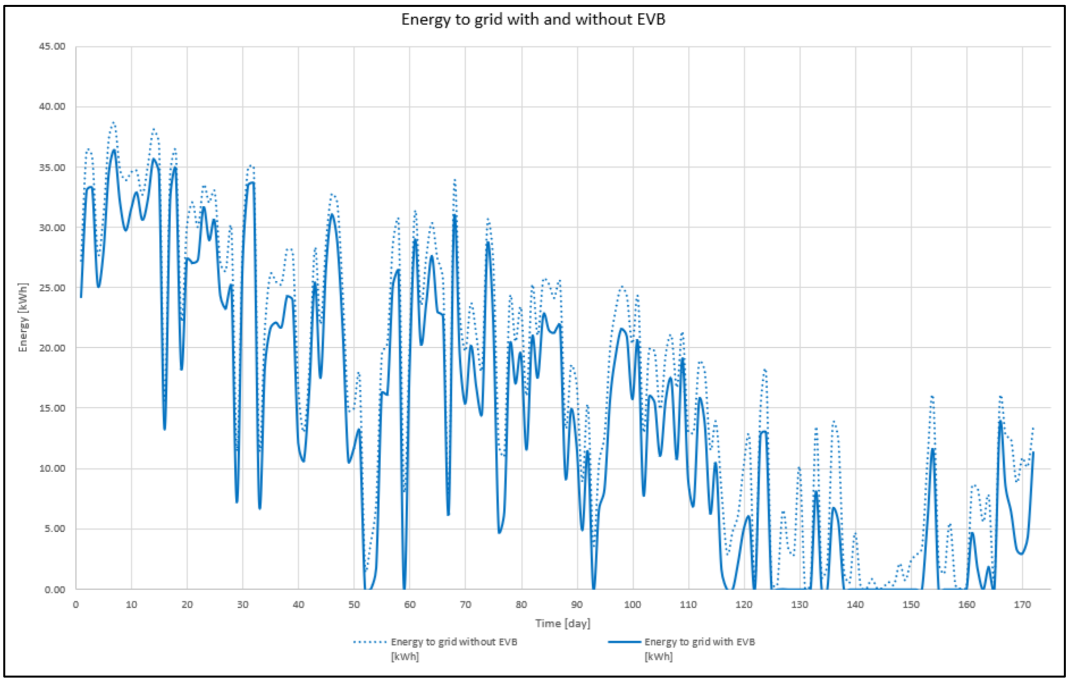

Fig. 3. Energy fed into grid

- maximized own consumption from ON-Grid PV system (Fig. 4)

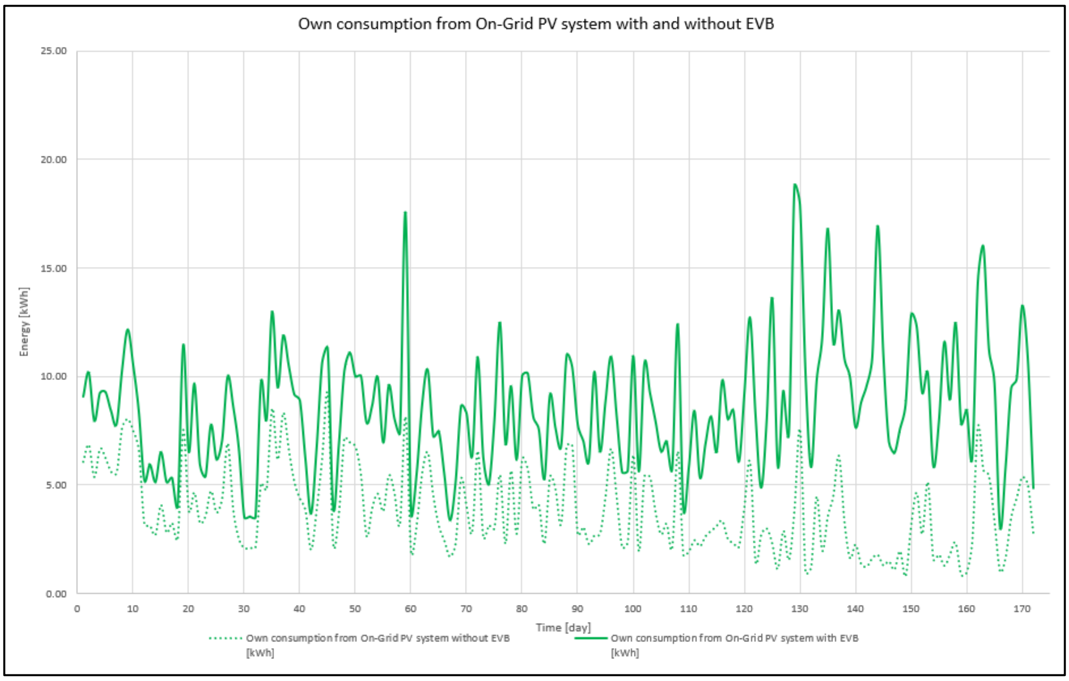

Fig. 4. Own consumption values

- minimized energy absorbed from grid (Fig. 5)

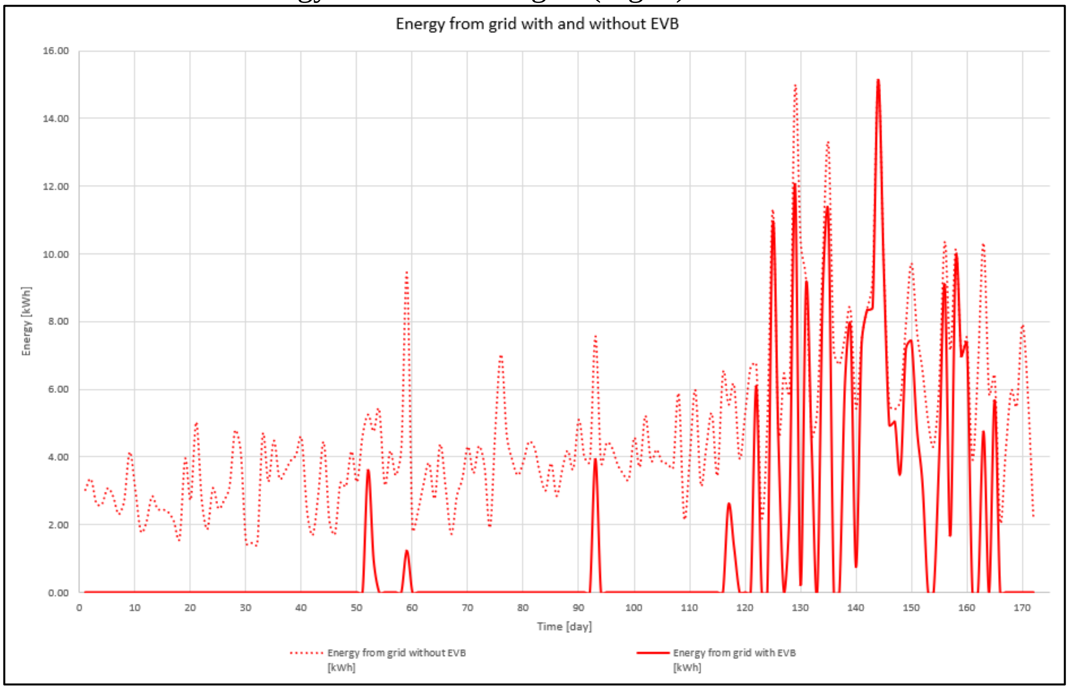

Fig. 5. Energy from grid values

5. Conclusions

In conclusion, the choice of the type of automation depends on factors such as the nature of the manufacturing process, product variety, adaptability requirements, initial investment, and available expertise. Fixed automation is best suited for highly repetitive tasks, while programmable automation is more versatile. Flexible automation is ideal for variable production, and integrated automation offers the highest level of automation and adaptability but comes with greater complexity and costs. Organizations should carefully assess their specific needs and goals when selecting the most appropriate automation approach.

As we continue to embrace the digital age, it is evident that industrial automation is not just a trend, but a fundamental change that will shape the future of industries around the world. Further research is needed to explore the full potential of automation technologies and address the challenges associated with their implementation.

The results obtained in this paper show the benefits of applying fixed automation in a photovoltaic system with the integration of used electric vehicle batteries. Improving energy storage capabilities and enabling the efficient harnessing of solar energy even during non-sunlight hours demonstrate the importance of improving processes through automation. This approach not only increases the reliability and grid stability but also paves the way for more widespread adoption of clean energy technologies.

Regarding the integration of EVB second life in photovoltaic systems, this represents a paradigmatic shift towards a cleaner, more sustainable and economically viable energy context. It demonstrates the power of innovative thinking and collaboration in addressing the pressing challenges of our time while fostering a future where renewable energy sources take center stage in meeting our global energy needs. This innovative approach merges the dual benefits of recycling used batteries while reinforcing the adoption of solar power. It's a win-win solution that reduces waste, lowers costs, and extends the functional life of lithium-ion batteries.

R E F E R E N C E S

[1]. *M. Touseef, S. Siddiqui, N. Farah*, "Understanding the Role of Automation in Society", Praxis International Journal of Social Science and Literature, **Vol.** 6, Iss. 3, 2023, pp. 51-62

[2]. *** https://www.mwes.com/capabilities/assembly-and-automation/fixed-automation-systems/, Accessed on 24.05.2023

[3]. *** https://www.empoweredautomation.com/what-is-fixed-automation, Accessed on 24.05.23

[4]. *S. Singh, S. Anand, M.K. Satyarthi,* "A Comprehensive Review of Smart Home Automation Systems", Advances in Computer Science and Information Technology, **Vol.** 10, Iss. 2, 2023, pp. 61-66

[5]. *A. D. Encheș, A. R. Bordianu, O. M. Ghiță,* "The economic benefits of smart homes", U.P.B. Sci. Bull., Series C, **Vol.** 85, Iss. 1, 2023, pp. 315-326
[6]. *G. Karuna, R.P. Ram Kumar, R. Kapse, S. Revulagadda*, "Home Automation Based on IoT", 4th International Conference on Design and Manufacturing Aspects for Sustainable Energy, E3S Web of Conferences, **Vol.** 391, 2023, 01159, pp. 1-5
[7]. *A.S. Abdulraheem, A.A. Salih, A.I. Abdulla, M. Sadeeq, N. Salim, H. Abdullah, F. Khalifa, R.A. Saeed,* "Home Automation System based on IoT", Technology Reports of Kansai University, **Vol.** 62, Iss. 05, 2020, pp. 2453-2464
[8]. *D, McKay*, "Robotic Process Automation", International Journal of Research and Analytical Reviews, **Vol.** 10, Iss. 2, 2023, pp. 338-343
[9]. *E. Hofmann, M. Rusch,* "Industry 4.0 and the current status as well as future prospects on logistics", Computers in Industry, **Vol.** 89, 2017, pp. 23-34
[10]. *S. Elhajjar, L. Yacoub, H. Yaacoub,* "Automation in business research: systematic literature review", Information Systems and e-Business Management - article, 2023
[11]. *M. Ciurescu-Țibrian, I. Ciobanu, A. Mandiș*, "Power quality improvement using automation systems in electrical distribution networks", U.P.B. Sci. Bull., Series C, **Vol.** 84, Iss. 1, 2022, pp. 249-260
[12]. *C. Ferrara, R. Ruffo, E. Quartarone, P. Mustarelli*, "Circular Economy and the Fate of Lithium Batteries: Second Life and Recycling", Advanced Energy and Sustainability Research, **Vol.** 2, Iss. 10, 2021, 2100047, pp. 1-13
[13]. *K. Novakova, A. Prazanova, D.I. Stroe, V. Knap*, "Second-Life of Lithium-Ion Batteries from Electric Vehicles: Concept, Aging, Testing, and Applications", Energies, **Vol.** 16, 2023, 2345, pp. 1-19
[14]. *M.F. Borner, M.H. Frieges, B. Spath, K. Sputz, H.H. Heimes, D.U. Sauer*, "Challenges of second-life concepts for retired electric vehicle batteries", Cell Reports Physical Science, **Vol.** 3, Iss. 10, 2022, 101095, pp. 1-19
[15]. *A. Chadly, E. Azar, M. Maalouf, A. Mayyas*, "Techno-economic analysis of energy storage systems using reversible fuel cells and rechargeable batteries in green buildings", Energy, **Vol**. 247, 2022, 123466, pp. 1-16
[16]. *A. Rahil, E. Partenie, M. Bowkett, M.H. Nazir, M.M. Hussain*, "Investigating the possibility of using second life batteries for grid applications", Battery Energy, **Vol.** 1, Iss. 3, 2022, pp. 1-16
[17]. *** https://media.toyota.fr/construction-et-lancement-dun-systeme-de-stockage-denergie-large-spectre-de-grande-capacite-reposant-sur-la-reutilisation-de-batteries-de-vehicules-electrifies-reliees-au-reseau-electrique/, Accessed on 20.05.2023
[18]. *** https://docs.arduino.cc/hardware/mega-2560, Accessed on 20.05.2023
[19]. *** https://www.sharp-romania.ro/img/produse/1-15000/474/Fisa%20tehnica~Sharp%20NU-JD540.pdf, Accessed on 24.05.2023
[20]. *** https://www.fronius.com/en-us/usa/solar-energy/installers-partners/technical-data/all-products/inverters/fronius-primo/fronius-primo-8-2-1-208-240, Accessed on 24.05.2023
[21]. *** https://www.fronius.com/en/solar-energy/installers-partners/technical-data/all-products/system-monitoring/hardware/fronius-smart-meter/fronius-smart-meter-ts-100a-1, Accessed on 24.05.2023