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# Optimisation of solar power plant parameters for use in sprinklers in Southern Ukraine

**Abstract.** The study aimed to assess the effectiveness of integrating solar power plants into sprinklers in the Mykolaiv region. Modelling methods, practical tests and analysis of system efficiency were used to optimise the parameters of a solar power plant in the South of Ukraine. The results showed that for sprinklers in this region, a solar power plant should have sufficient capacity to meet the energy needs without significantly increasing the weight of the equipment. The most effective solution was to place the solar panels near the Zimmatic-354M machine, which ensures maximum solar energy production. The analysis showed that the use of batteries allows for uninterrupted operation of the system even with partial shading. Field tests confirmed the theoretical findings and revealed the need to improve the materials of the panels to increase their durability and resistance to dust and temperature fluctuations. Improvements to the design and use of new materials are recommended to increase the efficiency of the system in specific climatic conditions. The study also determined that the integration of solar panels into sprinklers would not adversely affect their manoeuvrability and stability. The results showed that the energy system, designed to meet the specific climatic conditions of southern Ukraine, can ensure the stable operation of sprinklers for a long time. In addition, the study revealed the need for regular maintenance of the panels to maintain their efficiency at the optimum level

**Keywords**: batteries; energy system; temperature fluctuations; maintenance; solar panel integration; agriculture

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## INTRODUCTION

In the South of Ukraine, where the level of solar radiation is quite high for most of the year, the use of solar power plants to power agricultural machinery is gaining relevance. One of the most promising areas is the integration of solar systems into the design of sprinklers. This can significantly reduce energy costs, which is an important factor in reducing the overall cost of farming, and contributes to the environmental friendliness of processes, reducing dependence on fossil energy sources. Solar power plants can provide sprinklers with the energy they need to operate, which can include powering pumps, drive wheels, control systems and other electronic components. However, to achieve maximum efficiency of such systems, specific operating conditions must be addressed. This includes assessing local climatic conditions such as temperature, humidity, rainfall and solar radiation intensity. It is necessary to optimise the parameters of solar systems, such as panel power, panel placement and battery efficiency, to ensure stable and uninterrupted operation of sprinklers. Optimisation of these parameters will not only reduce energy costs but also increase the overall efficiency of the system, which will affect the productivity of agricultural processes and the ecological balance in the region. Thus, research in this area is key to developing effective solutions that meet the requirements of the modern agricultural sector and the specific conditions of southern Ukraine.

Optimising the parameters of solar power plants for sprinklers is an important problem that requires a comprehensive approach to be solved effectively. Various aspects of this problem have been studied by different authors, but certain gaps require further research. A study by C.M. Kumar *et al*. (2023) confirms that solar panels can significantly reduce the energy costs of agricultural machinery while increasing its environmental friendliness. They also note that to maximise the benefits, it is necessary to properly consider local climatic conditions. O. Al-Shahri *et al*. (2021) analysed in detail the methods of optimising the placement of solar panels on machinery to improve their performance. This study shows that the correct positioning of solar panels can increase their efficiency by 20%. P. Chaurasiya *et al*. (2022) studied the impact of partial shading on solar panel performance and found that high-capacity batteries are critical to ensure stable system operation in variable conditions. Z. Quan *et al*. (2021) emphasised the importance of choosing materials for solar panels, in particular their ability to withstand high temperatures and dust. Y. Mases *et al.* (2021) demonstrated that the integration of solar systems into sprinklers can increase their autonomy, reducing the need for traditional energy sources and lowering operating costs. S. Gorjian *et al*. (2021) addressed the impact of different types of batteries on the efficiency of solar systems in the agricultural sector, pointing out the advantages of using modern lithium-ion batteries. M. Ghodki (2022) emphasised the need for regular maintenance of solar panels to maintain their efficiency, which is an important aspect of ensuring the smooth operation of sprinklers. A. Pascaris *et al*. (2021) demonstrated that properly configured solar systems can significantly improve the efficiency of agricultural processes, enabling farmers to reduce their energy costs. M. Jamali *et al*. (2021) highlighted that the integration of solar systems into sprinklers can help reduce greenhouse gas emissions, which has a positive impact on the environment. S. Alsadi & T. Foqha (2021) showed that to optimise the performance of solar systems, specific climatic conditions such as the frequency of sunny days and humidity levels need to be considered, which is particularly important for efficient operation. Thus, although there is a significant amount of research covering various aspects of solar power in agriculture, there are gaps in understanding the impact of the specific climatic conditions of southern Ukraine on the efficiency of such systems that require further study.

The study aims to determine the efficiency of using solar energy to power irrigation systems in the South of Ukraine. The objectives of the study are:

- to analyse the effectiveness of hybrid irrigation systems combining traditional methods with solar energy in the arid climate of the Mykolaiv region;
- to analyse the technical parameters of solar systems and their impact on the performance of sprinklers;
- to develop recommendations for improving the performance and durability of systems in specific climatic conditions.

## MATERIALS AND METHODS

The study was conducted at Mykolaiv National Agrarian University in 2024. The study carried out a comprehensive analysis and practical tests to optimise the parameters of a solar power plant for use in sprinklers in the Mykolaiv region of southern Ukraine.

The first step was to calculate the optimal capacity of the solar power plant to meet the energy needs of the sprinkler. This process included considering the insolation variability that is typical for the South of Ukraine. To ensure the smooth operation of the system, seasonal changes in insolation, daylight hours, and potential cloud cover, which can significantly affect the system's efficiency, were addressed. The task was to choose a system capacity that would guarantee the reliable operation of the machine even in adverse weather conditions while reducing energy costs. Calculating the required power of solar panels (1):

$$P_{panels} = \frac{P_{sys}}{H \times \eta}, \quad (1)$$

where $P_{panels}$ – power of the solar panels (kW); $P_{sys}$ – power consumption of the sprinkler (kW); H – average number of sunny hours per day (h); η – system efficiency (dimensionless value).

Calculating the area of solar panels (2):

$$A = \frac{P_{panels}}{\text{Power per } m^2}, \quad (2)$$

where Power per $m^2$ – power of solar panels per unit area ($kW/m^2$). An important part of the study was the determination of the optimal location for the solar panel on the Zimmatic-354M sprinkler (USA). Several options were considered, including the installation of panels on the roofs and sides of the machines. It was necessary to choose the location of the panels, which would minimise shading and maximise solar energy absorption. At the same time, the impact of the weight and size of the panels on the stability and manoeuvrability of the machine was analysed. It was necessary to ensure that the additional components did not reduce efficiency or adversely affect the machine's performance, including its cross-country ability and ability to work on different types of soil.

The study also included the development of an energy storage and management system. Efficient batteries were selected to provide sufficient energy storage to keep the system running during shading or at night. The development of control algorithms optimised the distribution of energy between the various working elements of the machine, as well as between the direct operation of the machine and battery charging. This was aimed at ensuring that the sprinkler operates stably regardless of external conditions, especially during periods of low insolation.

Another important aspect was modelling the system's performance under different climate scenarios specific to the South of Ukraine. Theoretical modelling was used to predict the system's operation during different seasons, which identified potential risks and assessed their impact on overall efficiency. This approach also provided for the possibility of adjusting the system parameters based on the results obtained, which could ensure stable operation even in conditions of partial shading and variable weather factors.

Technical and economic analysis was used to assess the efficiency of using different materials in the construction of solar systems in the South of Ukraine. This method was used to study the effect of materials on the durability and resistance of panels and batteries to dust, moisture and temperature fluctuations. Based on the results obtained, recommendations were developed to improve the design of the solar system, including the use of more efficient materials and improved panel design to reduce the impact of adverse climatic conditions such as dust storms.

## RESULTS

Agriculture, especially in southern Ukraine, is in constant need of efficient and reliable energy solutions. In this regard, the introduction of solar power plants to power agricultural machinery, including sprinklers, is one of the key areas for the development of the agricultural sector. However, to achieve maximum efficiency and productivity of such systems, it is necessary to calculate and optimise the capacity of the solar power plant to be used.

One of the most important aspects of this process is to consider the variability of insolation, i.e. the amount of solar energy reaching the Earth's surface in a particular region. In the South of Ukraine, where solar activity is quite high but subject to seasonal fluctuations, this factor is particularly important (Klymenko *et al.*, 2023). To ensure efficient operation of the sprinkler throughout the year, it is necessary to account for changes in insolation in different seasons, as well as the impact of daylight hours and potential cloud cover.

The main step in optimising the capacity of a solar power plant is to determine the energy needs of the sprinkler system. This includes analysing the power consumption in different operating modes and estimating the maximum loads that may occur during operation. It is important that the system capacity not only meets these needs but also provides a reserve in case of reduced efficiency due to deteriorating weather conditions or seasonal changes in insolation.

Seasonal changes in insolation are another important factor to consider when calculating system capacity. In summer, when solar activity is at its highest, the sprinkler can receive enough energy to run smoothly. However, in winter, when daylight hours are shortened and insolation levels decrease, there is a need for additional energy sources or a more powerful energy storage system that can keep the machine running even in partial or full shade (Oudes & Stremke, 2021).

In addition, when choosing the optimal capacity of a solar power plant, it is necessary to account for the possibility of cloud cover, which can significantly reduce the efficiency of the system. In this regard, it is advisable to provide a certain power reserve that will allow the sprinkler to operate stably even in adverse weather conditions.

Thus, choosing the optimal capacity of a solar power plant for sprinklers in Southern Ukraine is a multifactorial process that requires a careful analysis of the machine's energy needs, insolation variability, daylight hours and potential cloud cover. Only when all these conditions are met can the system operate stably and efficiently throughout the year, reducing energy costs and improving the environmental friendliness of agricultural processes.

Modern technologies are trying to ensure the integration of renewable energy sources into various areas of activity, and agriculture is no exception. Incorporating solar panels into the design of sprinklers, such as the Zimmatic-354M (Fig. 1), is one way to improve energy efficiency and reduce energy costs. The main technical parameters of this machine are shown in Table 1.

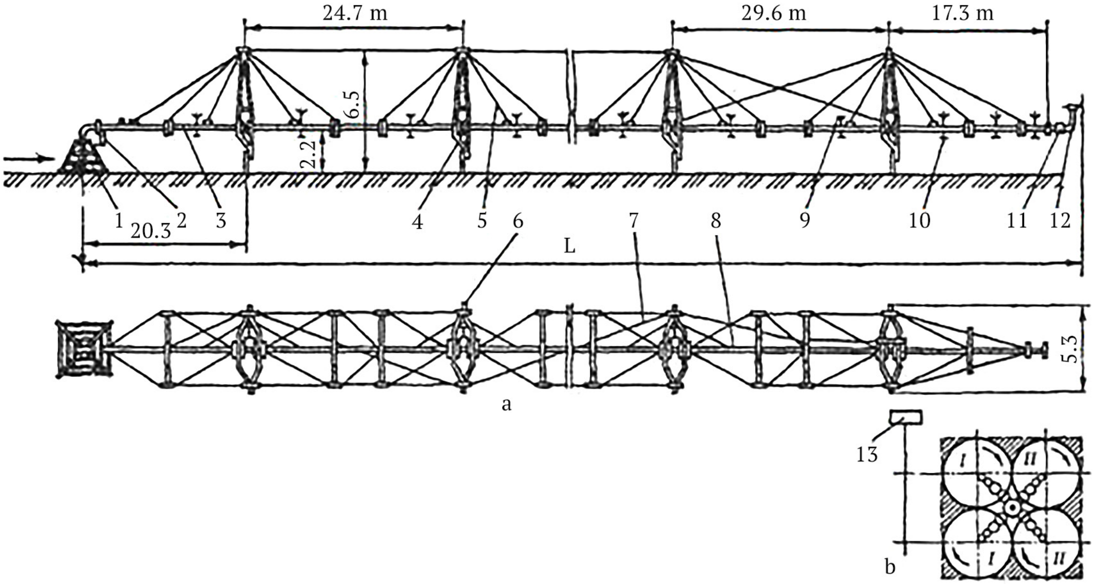


**Figure 1.** Diagram of the sprinkler Zimmatic-354M

**Note:** a – general view; b – irrigation scheme of two machines at two positions; 1 – fixed support; 2 – stop device; 3 – water pipeline; 4 – trolley; 5, 6, 7 and 8 – cable systems for automatic control of the trolley speed, as well as mechanical and electrical protection; 9 – sprinklers; 10 – drain valve; 11 – system for shutting down the final sprinkler; 12 – final sprinkler; 13 – pumping station

**Source:** Spraying Machine Zimmatic-354M (n.d.)

**Table 1.** Experimental data of the prototype sample of the SEMC

| | |
|---|---|
| Pressure at the machine inlet, MPa | 0.3 |
| Water consumption, l/s | 81.4 |
| Operating width, m | 354 |
| Productivity, ha per hour of working time (m = 600 m$^3$/hour) | 0.49 |
| Specific fuel consumption, l/ha | 2.8 |
| Effective irrigation coefficient | 0.77-0.84 |
| Average rain intensity, mm/min. | 1.1 |
| Rated power of the generator, kW | 10 |
| Rated motor power, kW | 16.4 |

**Source:** Spraying Machine Zimmatic-354M (n.d.)

The sprinkler is designed for irrigation of grain, fodder, industrial and vegetable crops, including tall-stemmed crops, the sprinkler has a power trolley consisting of a support frame, supporting posts and crossbars, which are supported by two pneumatic wheels. This trolley is equipped with a power unit, fuel tank, water supply riser, diesel engine control panel, battery, main machine control panel, furrow guidance devices, limit switches and a flexible water hose.

The power unit, consisting of a diesel engine and a generator, is equipped with a control and monitoring panel with an emergency protection system for water temperature and oil pressure. The automatic guidance of the machine in the furrow is ensured by the tracking devices. The water pipeline, consisting of seven trusses, transports water to the sprinkler heads and is a prefabricated structure with hinged joints.

The kit includes low-pressure deflector nozzles with circular action and pressure regulators. The gear motor transmits the torque to the wheel gearbox via a propeller shaft. The gimbaled span joint consists of brackets welded to the pipe and a metal ring. The hydraulic connection between the spans is made by a rubber coupling wrapped in a steel cage. The control panel has manual process control and a percentage timer for setting the machine speed. The control system includes a control cabinet, trolley and machine synchronisation devices, stop sensors in a given sector and cable connections to ensure automatic control, monitoring and protection of the machine. The integration of such systems requires a careful approach to choosing the location of the panels, as well as analysing the impact of their weight and size on the machine's performance.

Choosing the optimal location for the solar panels on the Zimmatic 354M is critical to maximising the efficiency of the system. Options include mounting the panels on the roofs or sides of the machine. Placing the panels on the roof tends to maximise solar energy harvesting, as this part of the machine is usually less prone to shading by other objects such as vegetation or buildings (Selvi *et al.*, 2023). The roof also provides a large area for the panels to be placed, allowing for more energy to be captured from sunlight.

However, mounting the panels on the sides of the machine also has its advantages. This option can be useful for sprinklers that often operate in difficult conditions where the roof may be partially shaded or dirty. Side-mounted panels can help in cases where the roof cannot be used due to design or technical limitations. In addition, side panels can be easier to install and maintain. The placement of panels on any part of the machine also has an impact on its overall performance. One of the most important aspects to consider is the impact of the weight and size of the panels on the stability and manoeuvrability of the machine. Heavy solar panels can change the centre of gravity of the machine, which can affect its stability and driving behaviour. This is especially important for sprinklers that often operate on uneven or slippery surfaces.

The analysis of the impact of panel weight on machine stability includes an assessment of changes in the weight distribution and the impact on handling. It is necessary to ensure that the placement of the panels does not compromise the overall stability and manoeuvrability of the machine, which could affect its performance in the field. Technical solutions, such as using lighter materials for panels or weight distribution, can help maintain optimal machine performance (Ahmadnia *et al.*, 2022). Lastly, the integration of solar panels into the design of the Zimmatic-354M sprinkler requires a comprehensive approach to selecting their location and assessing their impact on performance. Carefully planned panel placement will help ensure maximum efficiency of the solar system while maintaining the stability and manoeuvrability of the machine. The successful integration of such systems can significantly improve the energy efficiency of sprinklers and help reduce their environmental impact.

Ensuring the smooth operation of sprinklers in agriculture is critical to maintaining a stable water supply and optimal crop growth. Modern technologies offer solutions to improve energy efficiency, one of which is the integration of energy storage and management systems using solar panels (Tan *et al.*, 2021). In this context, efficient batteries and the development of energy management algorithms that can ensure uninterrupted operation of the system even during shading or at night deserve special attention. Efficient batteries are a key component for storing energy from solar panels (Fagiolari *et al.*, 2022). They can be used to store excess energy during the day, when solar activity is at its highest, and used during periods when sunlight is not available, such as at night or during cloud cover. Choosing batteries with high energy density and long service life is important to ensure the stability of the sprinkler system. The batteries must be able to withstand charging and discharging cycles without significantly reducing efficiency to ensure reliable system operation.

The development of energy management algorithms is the next important step in ensuring efficient system operation. The control algorithms must optimally distribute energy among the various operating elements of the machine, such as pumps, control systems, and other power consumers (Sadeeq & Zeebaree, 2021). This includes developing strategies to prioritise energy allocation, ensure that critical functions have sufficient power, and optimise battery charging processes. This can be done using specialised software solutions that account for the current battery level, the energy needs of the machine and weather forecasts. The integration of energy storage and management systems not only increases the efficiency of solar energy use but also reduces dependence on external energy sources, which can be especially important in remote or hard-to-reach areas (Wang *et al.*, 2022). The smooth operation of the system is critical to ensure the proper functioning of sprinklers, as any decrease in efficiency can lead to insufficient watering of crops and, as a result, lower yields.

The use of efficient batteries for energy storage and the development of control algorithms for optimal energy distribution is integral to the successful integration of solar systems into sprinklers. This ensures stable operation of the equipment even in adverse weather conditions and at night, which significantly increases its efficiency and reliability in the field. Proper management of energy resources is key to ensuring the sustainable development of agricultural production and increasing its efficiency. Evaluating the performance of a solar panel system for sprinklers is a critical step in ensuring its successful implementation in real-world conditions. This includes using modelling to predict system performance under different climate scenarios and conducting field trials to verify theoretical calculations and adjust system parameters.

System performance modelling is the first step in the process of assessing system efficiency. It can be used to predict how the system will perform in different climatic conditions, considering variable factors such as solar radiation intensity, temperature, humidity and seasonal fluctuations. Computer simulations can predict how a system will respond to different scenarios, which can help identify potential problems and adjust the system design before actual testing begins. Modelling can also be used to optimise energy distribution, address changes in operating conditions, and determine the best parameters to ensure maximum efficiency.

To calculate the optimal power of solar panels for sprinklers in the South of Ukraine, the energy needs were first determined. The power consumption of the sprinkler is 5 kW. The following formula (3) was used to determine the required capacity of solar panels, given the average number of sunny hours per day, which is 5 hours in the South of Ukraine, and the system efficiency of 75%:

$$P_{\text{panels}} = \frac{5\ \text{kW}}{5\ \text{hours} \times 0.75} = 1.33\ \text{kW}. \quad (3)$$

The next step was to calculate the area of the solar panels. The average capacity of the solar panels is 300 W/m$^2$, or 0.3kW/m$^2$. The area of the panels is calculated using the formula (4):

$$A = \frac{1.33\ \text{kW}}{\frac{0.3\ \text{kW}}{\text{m}^2}} = 4.33\text{m}^2. \quad (4)$$

Thus, to ensure the smooth operation of a sprinkler with a power consumption of 5 kW in the conditions of average insolation in the South of Ukraine, the power of solar panels is about 1.33 kW, and the corresponding panel area will be about 4.43 $m^2$.

After the theoretical analysis, it was necessary to conduct field tests to confirm the theoretical calculations and identify the actual results of the system. The field tests verified the accuracy of the predictions made during the modelling phase (Table 2). It also contributed to the identification of problems that might not have been noticed during the theoretical calculations, such as unexpected effects from the interaction of solar panels with other machine components or the impact of unforeseen climatic conditions. The field trials provided real-world data on the system's performance that could be used for further improvements.

**Table 1.** Evaluation of the efficiency of the solar panel system for the Zimmatic-354M sprinkler

| Value | Description | Value | Note |
|---|---|---|---|
| Intensity of solar radiation | Average value of solar radiation intensity in different seasons | 800 W/$m^2$ (summer) | According to weather conditions |
| Temperature | Average temperature in different seasons | 30°C (summer) | May affect efficiency |
| Humidity | Average humidity levels that can affect system performance | 60% (humidity) | Affects the performance of the panels |
| Water consumption | Average water consumption provided by the system | 81.4 l/s | Indicated for the main time |
| Productivity | Total area that can be watered per hour | 0.49 ha/hour | Depends on the efficiency of the system |
| Fuel consumption per unit | Fuel consumption per unit of cultivated area | 2.8 l/ha | Depends on the operation of the machine |
| Effective irrigation coefficient | Ratio of actual watering to planned watering | 0.77-0.84 | Depends on the accuracy of the system |
| Average rain intensity | Rain intensity provided by the system | 1.1 mm/min | Affects the quality of watering |
| Rated power of the generator | The power of the generator that provides energy for the system | 10.0 kW | Affects system performance |
| Rated power of the motor | Power of the motor that drives the system | 16.4 kW | Impact on work efficiency |

**Source:** compiled by the authors based on A. Matheswaran *et al*. (2021)

Adjusting the system parameters based on the data is the next important step. If the field tests reveal deficiencies or opportunities for improvement, adjustments to the system design or control algorithms should be made accordingly. This may include optimising panel placement, improving batteries, or tweaking software to better manage energy. Flexibility in adjusting system parameters is key to ensuring that the system operates efficiently under conditions that may vary in real-world operating situations.

Evaluating the performance of a solar panel system in real-world conditions is an important process to ensure its success. Using modelling to predict performance and conducting field trials to validate theoretical calculations can ensure that the system is operating at maximum efficiency. It also helps identify possible problems and find solutions to address them, which in turn helps to improve the performance of sprinklers and ensure that they are stable in the real-world operating environment.

Solar systems used in sprinklers have significant potential to improve efficiency and reliability in the specific conditions of southern Ukraine (Atamanyuk *et al*., 2016). This region is characterised by extreme climatic conditions such as dust storms, high humidity and significant temperature fluctuations. To ensure the durability and performance of solar systems, it is necessary to address these factors and develop recommendations for improving the design and use of materials.

It is important to improve the design of solar panels to meet the specific conditions of southern Ukraine. Dust storms, which are common in the region, can have a negative impact on the efficiency of panels, reducing their performance and service life. To counteract this, it is necessary to use special protective coatings that would reduce the accumulation of dust on the surface of the panels. Additionally, the optimal location of the panels, considering the possibility of self-cleaning during rain or cleaning systems, can significantly increase their efficiency (Stavinskiy *et al*., 2021; Myyas *et al*., 2022).

High humidity is also an important factor affecting the efficiency of solar systems. Humidity can lead to corrosion and reduced panel performance. To prevent this, it is recommended to use materials that are resistant to moisture, such as specially treated panel coatings and sealed battery enclosures. This will help ensure the longevity of the system by preventing possible moisture-related problems (Dhass *et al*., 2022). Temperature fluctuations in southern Ukraine can affect the performance of solar panels and batteries. High temperatures can lead to overheating and reduced panel efficiency, while cold temperatures can reduce battery capacity. The use of heat-resistant materials and cooling systems for panels, such as heat sinks or passive cooling systems, can help maintain optimal temperatures and ensure consistent performance. Batteries should also be equipped with thermal management systems to maintain their efficiency in extreme temperatures.

An important aspect is the use of more efficient materials for the manufacture of solar panels and batteries. Modern materials with improved characteristics can increase the performance and durability of the system. For example, the use of panels with high efficiency can reduce the area required for panel installation while providing greater energy output. Newer generation batteries, with higher capacity and faster charging times, can improve overall system efficiency and reduce maintenance (Rubino *et al*., 2023). In the South of Ukraine, particularly in the Mykolaiv region, the efficient use of solar energy to power sprinklers is an important task to ensure sustainable crop irrigation. Given the high potential of solar energy in the region, optimising the parameters of a solar power plant is essential to increase the efficiency of irrigation systems and reduce dependence on traditional energy sources.

The first step in optimising a solar power plant is to choose the right capacity. For the Mykolaiv region, where the annual amount of solar radiation is about 1400-1500 kWh/m$^2$, it is advisable to choose a capacity that will ensure uninterrupted operation of sprinklers throughout the irrigation season (Avdieieva *et al*., 2022; Shahini *et al*., 2024). It is recommended to calculate the capacity of the plant accounting for the daily water consumption, pump efficiency and efficiency, as well as energy losses during transmission. For maximum power generation, it is necessary to determine the correct angle of inclination of solar PV modules. In the Mykolaiv region, the recommended angle of inclination should be approximately 30-35° to the horizon, which allows for the highest efficiency throughout the year (Global Solar Atlas, n.d.; Atamanyuk & Kondratenko, 2015). Seasonal changes in insolation and the possibility of adjusting the angle of inclination to increase productivity in summer should be considered. Given the unevenness of solar radiation throughout the day and weather fluctuations, it is advisable to introduce energy storage systems (batteries). This will ensure the uninterrupted operation of sprinklers even in conditions of insufficient power generation. It is recommended to choose batteries with high energy density and long service life to minimise operating costs.

The efficient operation of a solar power plant also depends on proper management and monitoring of its parameters. It is recommended to implement automated systems that monitor the performance of PV modules, the condition of batteries, and the energy consumption of power sprinklers. The use of modern data monitoring and analysis systems will help to quickly identify and eliminate possible malfunctions in the plant. Optimising the parameters of a solar power plant for use in sprinklers in the South of Ukraine requires a comprehensive approach, including the right choice of power, adjusting the angle of the PV modules, implementing energy storage systems and automating the control process. Adherence to these recommendations will increase the efficiency of irrigation systems, reduce operating costs and ensure a stable water supply in the region's unstable climate.

Implementation of these recommendations will significantly improve the efficiency and reliability of solar systems in the South of Ukraine. This will not only increase the productivity of sprinklers but also ensure their stable operation in extreme climatic conditions, which will help to improve the efficiency of agricultural processes in the region.

## DISCUSSION

The study on optimising the parameters of a solar power plant for use in sprinklers has yielded results that demonstrate the effectiveness of the proposed solutions. The focus was on calculating the optimal power of solar panels, taking into account the specific climatic conditions of the South of Ukraine. According to the data obtained, the chosen system capacity provided a stable power supply to sprinklers, even under conditions of variable insolation, which proved the effectiveness of the choice in practice. This was also investigated by H. Satria *et al*. (2021), where the results confirmed that the analysis of optimisation results focuses on comparing actual performance with predictions and assessing the impact of factors such as tilt angles and weather conditions. It is important to determine how effective the adjustments made, such as upgrading system components or improving control technologies, were and whether an increase in energy production was achieved. K. Hoffer & G. Savini (2021) also showed that assessing the effectiveness of the designed capacity involves comparing planned and actual performance, using metrics such as system performance factor, and considering financial aspects. It is important to determine how well the system meets energy needs and whether investments in its optimisation are justified. It is worth noting that optimising the capacity of solar panels can have a significant impact on the overall efficiency of the system (Babii & Sologub, 2023). Improving the accuracy of calculations and adjusting system parameters can lead to a significant increase in energy production and a reduction in energy costs. In addition, successful optimisation not only increases productivity but also improves the economic return on investment in solar energy. It is also necessary to consider that regular monitoring and analysis of performance allows for the timely detection and elimination of possible problems, which contributes to the long-term stability and reliability of the system.

After modelling the performance of the system, it was determined that the location of the panels on the roofs of the sprinklers was the most efficient (Stoliarov, 2024). The modelling confirmed that this option minimises shading and maximises solar energy absorption. After implementing the model in real-world conditions, the data confirmed that the optimal location of the panels allows for maximum energy efficiency, which has a positive impact on the overall performance of the sprinklers. S. Shorabeh *et al*. (2022)

concluded that the assessment of the optimal location includes the selection of the correct tilt angles and orientation of the panels to maximise solar radiation absorption. It is important to consider shading from surrounding objects to ensure maximum system performance. V. Gjorgievski *et al*. (2021) found that the location of the panels directly affects their efficiency. Incorrect tilt angle or orientation can reduce the amount of solar energy collected and the overall system performance. Considering seasonal changes in the sun's path is also important to ensure optimal results. These results confirm the above study, as they demonstrate that the optimal positioning of solar panels significantly increases their efficiency. In particular, the correct choice of panel angle and orientation, as well as the consideration of possible shading, confirm the importance of accurate calculations to maximise solar energy collection. This confirms that the results of the study adequately reflect the real conditions and the effectiveness of the proposed solutions.

The use of efficient batteries for energy storage also proved to be important. The batteries ensured uninterrupted operation of the system during periods of shade or night (Amidu *et al*., 2023). Tests confirmed that the selected batteries have sufficient capacity to cover the energy needs of the machines at night and during limited solar radiation, which ensured the reliability of the system. It is worth noting the work of T. Abdul-Jabbar *et al*. (2021), who also determined that batteries are critical to ensuring the smooth operation of solar systems by storing energy for use when the sun is not shining. Their efficiency is determined by capacity, charging and discharging speed, and service life. Modern batteries provide high performance, but their efficiency can vary depending on the type and operating conditions. In turn, D. Kong *et al*. (2021) concluded that the analysis of battery performance in different conditions includes an assessment of their performance when temperature and loads change. Cold temperatures can reduce efficiency, while high temperatures can cause overheating and shorten the service life (Smyk & Arkhypova, 2023). This analysis helps to optimise the system to ensure stable battery performance in different conditions. This data is consistent with the discussion in the previous section, as it confirms that battery efficiency is critical to the smooth operation of the system and demonstrates how different conditions affect battery performance. The results of the analysis confirm that the right choice of batteries and their proper operation are key to ensuring the stability and reliability of the power system. It also confirms the importance of considering variable conditions to optimise system performance.

The developed energy management algorithms have demonstrated their effectiveness in the optimal distribution of energy between the machine's working elements and battery charging. Modelling and field tests have shown that these algorithms reduce energy costs and increase the efficiency of using stored energy. This confirmed the need to fine-tune the control system to ensure stable operation in different conditions. D. Wang *et al*. (2021) also conducted a study that confirmed that the analysis of energy management algorithms helps to evaluate the effectiveness of real-time energy distribution planning and adaptive control. This includes identifying the benefits and limitations of algorithms, such as their ability to respond to load changes and store energy. Optimal algorithms can significantly improve system performance and reduce costs. J. Hu *et al*. (2021) also determined that optimising energy distribution includes the use of algorithms to increase resource efficiency, reduce energy losses, and improve load management. This helps to reduce costs by minimising energy losses and improving overall system efficiency. Comparing the data obtained in the course of the research, it can be concluded that the effectiveness of energy management algorithms has a significant impact on the overall system performance. The analysis shows that optimising energy distribution and using advanced algorithms can reduce costs and increase efficiency. These results confirm that the implementation of such algorithms is key to achieving high energy efficiency and economic benefits in power systems.

Field tests conducted in real-world conditions showed that the solar panel system can operate efficiently even under partial shading and variable weather conditions. This proved to be critical for ensuring the reliability of sprinklers, as variable weather conditions often affect the performance of solar power plants (Serikuly *et al*., 2022). The test results confirmed the theoretical calculations and allowed for timely adjustments to the system parameters. S. Fan *et al*. (2021) concluded that the impact of panels on energy efficiency is assessed through their ability to generate energy under test conditions. Different types of panels can show different performances depending on their characteristics. Tests can identify the advantages and disadvantages of panels, which helps to more accurately predict their performance in real-world conditions. C. Mokhtara *et al*. (2021) determined that determining system performance in a variable climate allows them to assess how changes in temperature and humidity affect solar panel performance. This helps to identify how climate conditions can change system efficiency and what adjustments are needed to maintain optimal performance. When analysing the results of the study, the efficiency of solar panels depends on their characteristics and operating conditions. Tests have shown that different types of panels react differently to changing climatic conditions, which confirms the importance of taking these conditions into account when designing and installing systems. Regular monitoring and adaptation of the system to climate change is essential to maintain stable performance and reduce negative impacts.

## CONCLUSIONS

Optimisation of the parameters of a solar power plant for sprinklers in the South of Ukraine is a critical step to ensure the efficient operation of the system in specific climatic conditions. The results of the study showed that the main factors for ensuring proper performance are the calculation of solar panel capacity, consideration of average insolation and system efficiency.

Modern technologies have actively integrated renewable energy sources into various fields of activity, including agriculture. The introduction of solar panels in the design of sprinklers, such as the Zimmatic-354M, has significantly improved the efficiency of energy systems, providing sustainable and reliable power in a specific climate.

The analysis showed that to meet the energy needs of the sprinkler, the solar panels need to have the appropriate capacity. This will provide enough energy for the system to operate smoothly under average insolation. The system's efficiency factor, which considers energy losses, was refined to determine the required panel capacity.

Further calculation of the panel area showed that to meet these needs, an appropriate panel area with optimal efficiency is required. This calculation will help to ensure the optimal placement of the panels for maximum solar energy absorption, considering possible seasonal fluctuations in insolation.

Through modelling and field tests, key aspects were identified to improve system efficiency, including adjustments to panel placement and improvements to the energy storage system. The recommendations made will help to improve the overall efficiency of solar power plants in sprinklers, which will ensure stable and reliable operation in the specific climatic conditions of southern Ukraine.

To further improve the solar power system in sprinklers, it is necessary to address the impact of different types of solar panels and batteries on the overall system efficiency under variable climatic factors and long-term operation. A limitation of the study is that the experimental tests were conducted only in the limited climatic conditions of southern Ukraine, which may not fully reflect the system's effectiveness in other regions with different weather characteristics.

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## CONFLICT OF INTEREST

None.

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# Оптимізація параметрів сонячної електростанції при використанні у дощувальних машинах в умовах Півдня України

**Анотація.** Дослідження мало на меті оцінити ефективність інтеграції сонячних електростанцій у дощувальних машинах в умовах Миколаївської області. У дослідженні були використані методи моделювання, практичні випробування та аналіз ефективності системи для оптимізації параметрів сонячної електростанції в умовах Півдня України. Результати показали, що для дощувальних машин у цьому регіоні сонячна електростанція повинна мати достатню потужність для забезпечення енергетичних потреб без значного збільшення ваги обладнання. Найбільш ефективним виявилося розміщення сонячних панелей біля машини Zimmatic-354M, що забезпечує максимальне отримання сонячної енергії. Аналіз показав, що використання акумуляторів дозволяє забезпечити безперебійну роботу системи навіть при частковому затіненні. Польові випробування підтвердили теоретичні висновки та виявили потребу в покращенні матеріалів панелей для підвищення їх довговічності та стійкості до пилу і температурних коливань. Рекомендовано вдосконалення конструкції та використання нових матеріалів для підвищення ефективності системи в специфічних кліматичних умовах. Також було встановлено, що інтеграція сонячних панелей до дощувальних машин не вплине негативно на їх маневреність і стійкість. Результати показали, що енергетична система, спроектована з урахуванням специфічних кліматичних умов Півдня України, здатна забезпечити стабільну роботу дощувальних машин протягом тривалого часу. Крім того, дослідження виявило необхідність регулярного обслуговування панелей для підтримання їх ефективності на оптимальному рівні

**Ключові слова**: акумуляторні батареї; енергетична система; температурні коливання; обслуговування; інтеграція сонячних панелей; сільське господарство