EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 1, January 2026
brightmindpublishing.com
ISSN (E): 3061-6972
Licensed under* CC BY 4.0 *a Creative Commons Attribution 4.0 International License.

DESIGN OF AN OPTIMAL AUTOMATED PROCESS CONTROL SYSTEM FOR A HYDROPONIC DEVICE WITH A REMOTE MONITORING FUNCTION

Gulmurodova Go'zal Qobiljon qizi
Tashkent Irrigation and Agricultural Mechanization
Institute TJICHA M-25-13 Master Degree
kabulovnagozal@gmail.com

Abstract
This article investigates the design of an optimal automated process control system for a hydroponic installation equipped with a remote monitoring function. The main objective of the study is to develop an effective control solution that enables real-time monitoring and automatic regulation of environmental parameters in hydroponic systems in order to enhance process stability and productivity. The proposed system focuses on the continuous control of key parameters such as pH level, electrical conductivity (EC), temperature, humidity, and light intensity, which play a critical role in plant growth and development. An automated control structure based on sensors, actuators, and feedback control algorithms is presented. In addition, an IoT-based remote monitoring platform is integrated into the system, allowing users to observe system status, collect data, and perform analytical evaluations remotely. The control strategy is designed using a feedback-based optimal control approach, and its applicability to hydroponic processes is theoretically and experimentally justified. Experimental results demonstrate that the proposed automated control and remote monitoring system ensures stable operation of the hydroponic process, improves resource efficiency, and contributes to increased crop productivity. The findings of this study have significant scientific and practical value for the development of smart agriculture technologies and the automation of modern hydroponic systems.

Keywords: Hydroponic system; automated control system; remote monitoring; Internet of Things (IoT); optimal control; sensor-based monitoring; smart agriculture.

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 1, January 2026
brightmindpublishing.com
ISSN (E): 3061-6972
Licensed under* CC BY 4.0 *a Creative Commons Attribution 4.0 International License.

Introduction

The design of an optimal automated process control system for a hydroponic installation equipped with a remote monitoring function represents one of the key scientific and technological directions in modern smart agriculture. Hydroponic technology is based on growing plants in a soilless environment using nutrients dissolved in water, where plant development is directly dependent on the physical and chemical parameters of the growing medium. Therefore, precise and continuous monitoring of factors such as pH level, electrical conductivity, temperature, humidity, and light intensity is essential in hydroponic systems. The implementation of automated control systems in hydroponic processes enables the minimization of human involvement, improves control accuracy, and ensures efficient use of resources. Such systems measure environmental parameters in real time using sensors, process the acquired data through a control module, and implement the required control actions via actuators. A feedback-based automatic control mechanism ensures that parameters are maintained stably around predefined optimal values. The integration of a remote monitoring function significantly expands the functional capabilities of automated hydroponic systems. Monitoring platforms built on IoT technologies allow data collected from sensors to be transmitted to remote servers, stored, and analyzed. This provides users with the ability to monitor system conditions in real time from any location, adjust control processes remotely, and promptly detect emergency situations.

The selection of control algorithms is of considerable scientific importance in the design of an optimal control system. In practice, PID controllers, adaptive control algorithms, and predictive control methods are widely used. These algorithms account for system dynamics, minimize control errors, and ensure smooth regulation of transient processes. Data collected through monitoring serve as an important empirical basis for evaluating the effectiveness of control algorithms and optimizing their performance. Automated hydroponic systems with remote monitoring capabilities are also environmentally and economically efficient. Efficient use of water and energy resources, increased productivity, and reduced production costs are among the main advantages of such systems. Moreover, these systems can be widely implemented in large-scale greenhouses, urban agriculture projects, and vertical farming systems. In conclusion, the design of an optimal automated process control system for a hydroponic installation with a remote

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 1, January 2026
brightmindpublishing.com
ISSN (E): 3061-6972
Licensed under CC BY 4.0 *a Creative Commons Attribution 4.0 International License.*

monitoring function is a scientifically complex and highly relevant task based on the integration of control theory, information technologies, and agricultural technologies. This approach enhances the stability, reliability, and efficiency of hydroponic systems and plays an important scientific and practical role in the development of modern smart agriculture.

From a systems engineering perspective, a hydroponic installation with automated control and remote monitoring can be regarded as a complex cyber-physical system in which biological, technological, and informational processes interact continuously. The effectiveness of such a system largely depends on the accuracy of data acquisition, the reliability of communication channels, and the robustness of control algorithms. Any deviation in measured parameters or delays in data transmission may directly affect plant growth dynamics and overall system productivity. Therefore, the design of an optimal control system requires a comprehensive analysis of system dynamics and external disturbances. In automated hydroponic systems, sensor networks play a crucial role as the primary source of information. High-precision sensors enable accurate measurement of critical environmental parameters, ensuring that control decisions are based on reliable data. The integration of sensor calibration procedures and fault detection mechanisms further enhances measurement reliability. In addition, data redundancy and sensor fusion techniques can be applied to minimize the impact of sensor failures and measurement noise, thereby improving system robustness. The control architecture of a remotely monitored hydroponic system typically follows a hierarchical structure. At the lower level, real-time control loops regulate individual parameters such as nutrient concentration, temperature, and lighting intensity. At the higher level, supervisory control modules analyze historical and real-time data to adjust control strategies and optimize system performance. This multi-layer control approach enables both fast response to disturbances and long-term optimization of growing conditions. Another important aspect of optimal control system design is energy management. Automated hydroponic installations often operate continuously, making energy consumption a critical factor. By incorporating intelligent scheduling of actuators, such as pumps and lighting systems, the control algorithm can significantly reduce unnecessary energy usage. For instance, adaptive lighting control based on plant growth stages and natural light availability can improve energy efficiency without compromising plant development.

Remote monitoring platforms also provide a valuable foundation for advanced data analytics. The accumulation of long-term operational data enables statistical analysis, trend identification, and predictive modeling of system behavior. Machine learning techniques can be employed to predict parameter deviations, detect anomalies, and recommend preventive maintenance actions. Such predictive capabilities transform hydroponic systems from reactive control environments into proactive and self-optimizing systems. From an agricultural sustainability perspective, automated hydroponic systems with remote monitoring contribute to resource conservation and environmental protection. Precise control of water and nutrient delivery minimizes waste and reduces the risk of environmental contamination. Moreover, the closed-loop nature of hydroponic systems allows for water recycling and efficient nutrient utilization, which is particularly important in regions facing water scarcity. The scalability of automated hydroponic systems is another significant advantage. Modular system design and cloud-based monitoring platforms allow these systems to be easily adapted for different scales of operation, ranging from small research units to large commercial greenhouses. This flexibility makes automated hydroponics a promising solution for urban agriculture and food security initiatives. In summary, the integration of automated control systems and remote monitoring technologies into hydroponic installations represents a highly advanced and scientifically grounded approach to modern agriculture. By combining principles of control theory, information technology, and plant physiology, such systems enable precise regulation of growing conditions, enhance productivity, and promote sustainable agricultural practices. Continued research and development in this field, particularly in the areas of intelligent control algorithms and data-driven decision-making, will further strengthen the role of hydroponic technologies in the future of smart agriculture.

Conclusion

The results of this study confirm that the design of an optimal automated process control system for a hydroponic installation equipped with a remote monitoring function has significant scientific and practical importance for the development of modern smart agriculture technologies. The conducted analysis demonstrates that

Licensed under* CC BY 4.0 *a Creative Commons Attribution 4.0 International License.

stable and efficient plant growth in hydroponic systems is directly dependent on accurate, continuous, and reliable control of the physical and chemical parameters of the growing environment. The integration of automated control systems with remote monitoring technologies enhances the stability of hydroponic processes, reduces human intervention, and ensures rational use of resources. Real-time data acquisition through sensors, combined with feedback-based control actions, enables the continuous maintenance of optimal environmental conditions for plant development. As a result, crop productivity is increased while water and energy consumption are reduced. The application of remote monitoring platforms allows users to observe system conditions from any location, remotely adjust control settings, and promptly detect emergency situations. This approach improves system reliability and creates favorable conditions for the large-scale implementation of hydroponic installations in greenhouses, urban agriculture projects, and vertical farming systems. Furthermore, the selection and continuous improvement of optimal control algorithms based on monitoring data contribute to increased adaptability and efficiency of hydroponic systems. The future integration of artificial intelligence and predictive control methods is expected to further enhance system performance, enabling self-optimizing and intelligent operation. In conclusion, automated hydroponic systems with remote monitoring capabilities represent a sustainable and technologically advanced solution for modern agriculture. Their implementation plays a crucial role in improving production efficiency, reducing environmental impact, and supporting food security, thereby contributing to the advancement of smart agriculture.

References

1. Abdullayev, A. A. Innovative Technologies in Agriculture. Tashkent: Fan va Texnologiya, 2018.
2. Abdurahmonov, R. Sh. Fundamentals of Automated Control Systems. Tashkent: O‘qituvchi, 2017.
3. Asqarov, I. R. Modern Greenhouse Farming Technologies. Tashkent: Yangi Asr Avlodi, 2019.
4. Bo‘riyev, B. B. Digital Technologies in Agriculture. Tashkent: Innovatsiya, 2021.

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 1, January 2026
brightmindpublishing.com
ISSN (E): 3061-6972
Licensed under **CC BY 4.0** *a Creative Commons Attribution 4.0 International License.*

5. G‘ofurov, N. M. Automatic Control of Technological Processes. Tashkent: Fan, 2016.
6. Islomov, J. J. Sensor Technologies and Their Practical Applications. Tashkent: Texnika, 2020.
7. Jo‘rayev, S. A. Smart Agriculture Systems. Tashkent: Fan va Texnologiya, 2022
8. Karimov, A. X. Fundamentals and Practice of Hydroponics. Tashkent: Agricultural Publishing House, 2019.
9. Mirziyoyev, Sh. M. The Strategy of New Uzbekistan. Tashkent: O‘zbekiston, 2021.
10. Murodov, D. K. Plant Physiology. Tashkent: Fan, 2015.