

DESIGN AND CONCEPT OF AUTOMATIC ELECTRIC POWER ACTIVATION CONTROL SYSTEM IN AQUAPONICS USING MULTI-PERSPECTIVE APPROACH

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Abstract

Efficiency and energy savings in daily life have become a global focus, concretely embodied in one of the Sustainable Development Goals (SDGs), particularly under the seventh goal, "Affordable and Clean Energy," which aims to double the rate of improvement in energy efficiency. The trend of automation in agricultural and urban farming systems plays a significant role in electricity usage, which, if not managed properly, could lead to wasteful and inefficient energy consumption. In automated farming and cultivation models, such as aquaponic systems, electrical energy is required to operate automation systems and to activate all environmental engineering components, including pump motors, lighting, sensors, control devices, and data processors. Energy efficiency in farming and cultivation systems is essential to achieve the 2030 Sustainable Development Agenda, specifically ensuring food availability (food security) by applying principles of energy efficiency and renewable energy. This study proposes the design and conceptualization of an energy efficiency system for aquaponic models through an automatic power activation control system based on timing and light conditions, measured using an LDR sensor integrated into the aquaponic model. The data obtained are processed using a multi-perspective approach in the decision-making process to determine when the electrical power should be activated in the aquaponic system. The results demonstrate that the multi-perspective approach, incorporating light and time parameters, provides better power control outcomes compared to a single-perspective approach applied to individual parameters.

Keywords: Aquaponic systems, Automation, Energy efficiency, Sustainable development goals

INTRODUCTION

One of the 2030 global agendas within the Sustainable Development Goals (SDGs) is to ensure affordable, reliable, sustainable, and modern energy for all, as outlined in SDG 7. This goal emphasizes the importance of improving energy efficiency to reduce energy consumption and carbon emissions (Palippui, 2024).

Food security is a critical global issue addressed in the 2030 agenda, emphasizing the need for innovative and sustainable agricultural systems, such as aquaponics, to meet global food demands while preserving ecosystem balance (Ghaffar *et al.*, 2024). For urban communities, aquaponics presents an appealing solution, enabling local food production in limited urban spaces. The integration of automation and artificial intelligence further enhances the efficiency and productivity of aquaponics systems, making them an ideal approach for urban farming (Arthy, 2023; Kolhapuri *et al.*, 2024).

The use of electrical energy in aquaponics systems is essential for several vital operations, such as regulating water circulation and aeration through water pumps and aerators (Febriani *et al.*, 2024; Karimanzira & Rauschenbach, 2018). Additionally, it also supports artificial lighting and environmental condition monitoring (Alam *et al.*, 2023).

Automation in modern aquaponic systems has been increasingly adopted by practitioners and enthusiasts, enabling real-time monitoring and control of various parameters to enhance yields and maintain ecosystem health more effectively. While automation and the continuous operation of system components offer significant benefits, energy consumption and system efficiency remain critical considerations. Excessive energy use, particularly from lighting, poses challenges, underscoring the need for energy-efficient strategies to ensure the economic sustainability of aquaponics systems (Gillani *et al.*, 2022). Additionally, although automation minimizes manual intervention, it is essential to maintain and calibrate the system regularly to prevent malfunctions that could disrupt the ecosystem (Jaya *et al.*, 2024).

This study proposes an automated power activation control model for aquaponic systems using a multi-perspective approach that integrates two types of sensors: timing sensors and light intensity sensors. The model is designed to optimize energy utilization while maintaining the health of the aquaponic ecosystem, ultimately aiming to enhance crop yields and ensure the overall sustainability of the system.

The implementation of this model is expected to provide new insights into how technology can contribute to energy savings in the realization of more efficient and environmentally friendly agricultural practices.

LITERATURE REVIEW

Creating an automated system to activate power based on time using a Real-Time Clock (RTC) involves integrating hardware and software components to ensure precise time management and control. The RTC module is crucial for applications requiring accurate timing, such as power control systems, system activation, and other scheduling operations. Such systems typically employ microcontrollers like the ATmega328P or Arduino UNO to interface with the RTC module. These microcontrollers process time data and control the activation of connected devices according to predefined schedules (Pawar, 2022; Kasiselvanathan *et al.*, 2022).

RTC modules, such as the DS3231, are responsible for maintaining accurate time and date information. These modules are often paired with EEPROM for additional data storage, ensuring the system can operate independently of its primary power supply (Amiruddin & Fadlil, 2023). The user interface, often comprising an LCD screen and input devices such as rotary encoders or keypads, enables users to set and adjust activation times. This interface provides real-time feedback and control over system operations (Pawar, 2022; Kasiselvanathan *et al.*, 2022). The system employs relays or similar components to switch devices on or off at predetermined times. This mechanism is crucial for applications such as power control systems and automated activation, where precise timing is essential to optimize resource utilization (Pawar, 2022; Yuana *et al.*, 2023).

Automated systems can effectively manage electrical devices, reducing manual intervention and enhancing safety. These systems can be programmed to operate devices at specific times, improving energy efficiency and user convenience (Pawar, 2022). In agriculture, RTC-based systems can automate irrigation schedules, integrating sensors to adjust to environmental conditions like rainfall. This approach conserves water and boosts crop yields by ensuring timely watering (Yuana *et al.*, 2023).

While RTC-based systems provide significant advantages in automation and time management, they require careful design and implementation to ensure accuracy and reliability. Challenges such as maintaining system stability and adapting to environmental changes must be

addressed to maximize the benefits of these systems. Additionally, integrating user-friendly interfaces and remote control capabilities can enhance the usability and flexibility of the systems, making them suitable for a wide range of applications.

Developing an automated system to activate electrical components within an indoor aquaponic prototype based on light conditions using a Light Dependent Resistor (LDR) necessitates the integration of various technologies and methodologies. The system must be capable of monitoring light intensity and automatically adjusting electrical components, such as grow lights, to maintain optimal conditions for plant growth. This objective can be achieved through the implementation of microcontrollers, sensors, and actuators. The use of Light Dependent Resistors (LDR) to automate the activation of electrical power flow to a system is a well-established method, particularly in applications such as street lighting and residential demand response. LDRs function as sensors that detect ambient light levels and trigger the appropriate electrical circuits. This automation not only enhances operational efficiency but also contributes to energy conservation by ensuring that electrical systems are activated only when needed.

LDRs are commonly used in automatic street lighting systems to control the activation of lights based on ambient light conditions. When light levels fall below a certain threshold, the LDR triggers the circuit to turn on the lights, and conversely, it turns them off when sufficient sunlight is detected. This eliminates the need for manual operation and reduces energy consumption by preventing lights from being left on unnecessarily during the day (Patil & K, 2023). The system operates by using the LDR to control a transistor, which acts as a switch. The transistor switches between saturation and cutoff regions based on the LDR input, thus controlling a relay that powers the light (Patil & K, 2023).

Integrating a Real-Time Clock (RTC) and Light-Dependent Resistor (LDR) to control system activation can be approached from various perspectives, incorporating insights from fields such as sensor systems, real-time monitoring, and multi-modal control. This integration can enhance system efficiency by utilizing both time-based and light-based inputs to optimize activation patterns.

The concept of multi-perspective visual servoing, as discussed in the context of reinforcement learning, can be adapted to integrate RTC and LDR inputs. By utilizing reinforcement learning, the system can learn an optimal activation policy based on time and light conditions, similar to how visual states are used to predict robot actions (Zhang *et al.*, 2023). The Perspective Control approach addresses the challenge of integrating multiple sensor feeds by allowing users to control and navigate between different sensor perspectives. This can be applied to RTC and LDR by treating them as distinct sensor inputs that need to be coordinated for effective system control.

In mixed criticality real-time systems, a multi-mode monitoring approach allows for dynamic switching between configurations based on observed patterns. This can be applied to RTC and LDR by adjusting system activation dynamically based on time and light conditions, ensuring optimal resource utilization (Neukirchner *et al.*, 2013). The activation control system framework can be adapted to integrate RTC and LDR inputs, where the system responds to changes in power supply voltage and light conditions to manage activation. This involves using control signals to manage the power supply based on the combined inputs from RTC and LDR.

By using activation rules in a multi-context system, the relevance of RTC and LDR inputs can be modeled based on their reciprocal dependencies. This enables flexible activation control, where the system can determine which input to prioritize under different conditions (Mandl & Ludwig, 2010).

While the integration of RTC and LDR for system control offers many benefits, it is important to consider potential challenges, such as the complexity of managing multiple inputs and ensuring seamless coordination between them. Additionally, the system design must account for variability in

light conditions and the accuracy of time-based triggers to maintain reliability and efficiency. These considerations highlight the need for system design and testing to ensure successful implementation.

RESEARCH METHOD

The study conducted in this article proposes a design for an automatic power activation system in an aquaponic system using a time-based approach and a light condition-based approach in the surrounding aquaponic environment, collectively referred to as a multi-perspective approach.

The timing process in the proposed system employs an RTC (Real-Time Clock) type DS1307, configured to send activation signals to the controller used, namely the Arduino Mega2560, at 6:00 AM to power on the electrical system and at 6:00 PM to power off the system. The systems controlled for power activation in this study include the water pump system for aquaponic irrigation, the main power system for artificial lighting, and the sensor system used to monitor environmental conditions within the aquaponic system.

In addition to time-based control, another control perspective employed in this study involves measuring the light intensity around the aquaponic environment to ensure energy efficiency in the operation of the water pump and other components. Light intensity measurement is performed using LDR sensors, which monitor the level of light intensity in the surrounding aquaponic environment.

Thus, the relationship between the input devices, control devices, and output devices can be seen in Figure 1.

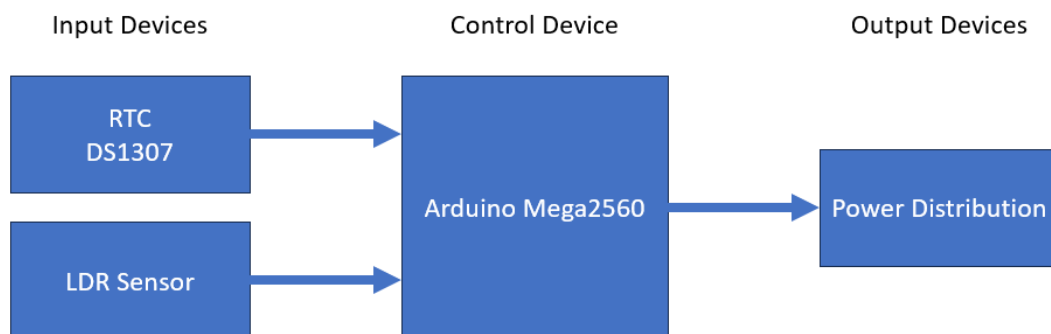


Figure 1. System block diagram: Input – Process – Output Devices

The primary perspective utilized in this study is the timing system, which, by default, activates the water pump and other equipment at 6 AM and deactivates them at 6 PM. However, to enhance energy efficiency, the water pump does not need to operate at certain times between 6 AM and 6 PM, specifically when evaporation is not occurring at maximum levels within the aquaponic system. One measurable parameter to determine the level of maximum evaporation is the sunlight condition in the aquaponic system environment, as higher sunlight intensity positively correlates with increased evaporation within the system.

Therefore, sunlight intensity measurement data in the aquaponic environment is used as an additional parameter or perspective in the automation system for electrical power usage in the aquaponic system. Data from the LDR sensor will be evaluated by the Arduino Mega2560. If the measured sunlight intensity falls below the predetermined threshold, even during the designated activation period for the water pump, the pump will be turned off as its operation does not significantly impact the irrigation needs within the aquaponic system.

The Arduino Mega2560 device used in this study has the ability to read voltage data in the range of 0 to 5 Volt DC, which is scaled to a value range of 0 to 1023. Based on this range, light detection is considered when the voltage reading exceeds a value of 650, or when the LDR sensor voltage exceeds 3.2 Volt DC. The value of 650 was obtained from light intensity measurements taken at 7 AM and 5 PM, when the plants undergo minimum photosynthetic activity.

Data sampling for light intensity is collected periodically every hour. This approach aims to preserve the lifespan of the components or load equipment used, such as the water pump motor, which can experience wear if frequently turned on and off within short intervals. Therefore, to maintain the longevity of the equipment, sampling is conducted once every hour.

RESULTS AND DISCUSSION

The tests conducted in this study aim to evaluate (1) the automation system for activating electrical power by default based on the timing system, (2) the additional perspective system, and (3) compare the energy efficiency of electricity usage between the conventional pump activation system and the multi-perspective system proposed in this study.

In the testing of the automation system for activating electrical power by default based on the timing system, the set points used and configured to activate the system were set for 6:00 AM local time. Consequently, in the RTC DS1307, the time was configured to 10:00 PM GMT (as the default time setting in the RTC refers to GMT). Similarly, to deactivate the system at 6:00 PM local time, the RTC DS1307 was set to 10:00 AM GMT. The system was tested over five days, and the results showed that it successfully automated the activation and deactivation of the main power system for the pumping system and artificial lighting.

In the testing process involving the addition of another perspective through the light intensity measurements, six LDR sensors were used to measure the light intensity in the aquaponic system environment. The data from these six LDR sensors were processed using a selection logic approach based on the scenarios established in this study. The scenarios used are as follows:

1. If all LDR sensors detect sunlight intensity above the specified threshold, it is assumed that maximum evaporation is occurring, and the water pump needs to be activated
2. If none of the LDR sensors detect sunlight intensity above the specified threshold, it is assumed that minimal evaporation is occurring, and the water pump does not need to be activated.
3. If at least four LDR sensors detect sunlight intensity above the specified threshold, it is assumed that moderate evaporation is occurring, and the water pump needs to be activated.

The testing was conducted by collecting data from 7 AM to 5 PM, rather than from 6 AM to 6 PM, because at 6 AM and 6 PM, sunlight intensity is minimal, and it is assumed that none of the LDR sensors would detect sunlight. The threshold value applied in this study is 650.

Table 1. Sunlight intensity measurement data

Time	LDR 1	LDR 2	LDR 3	LDR 4	LDR 5	LDR 6
7 AM	433	467	420	421	443	456
8 AM	481	495	488	499	491	422
9 AM	574	673	591	689	544	682
10 AM	642	685	637	711	692	700
11 AM	723	776	704	728	744	738
12 AM	873	881	892	899	902	917
1 PM	927	912	944	1002	1016	1020

2 PM	812	793	805	954	728	805
3 PM	688	603	672	678	598	663
4 PM	624	622	618	601	612	590
5 PM	322	275	341	305	339	372

From the experiments conducted, as shown in Table 1, it is observed that the first scenario occurred at 11 AM, 12 PM, 1 PM, and 2 PM. During these times, the water pump was required to remain active to prevent water shortages in the aquaponic piping system and to enhance oxygen levels at the plant roots for photosynthesis. The second scenario occurred at 7 AM, 8 AM, 4 PM, and 5 PM, during which the water pump was not needed because the sunlight intensity was not significant. The third scenario was never met, as there were no instances where at least four sensors but not all sensors measured light intensity above the threshold value.

Referring back to Table 1, at 9 AM, 10 AM, and 3 PM, the water pump was not activated in accordance with the rule outlined in Scenario 3, as the condition of at least four LDR sensors detecting light intensity above the threshold was not met.

In the conventional system, when the water pump is activated solely based on the timing system, the pump will run continuously from 6 AM to 6 PM, or for 12 hours. If the water pump uses 80 watts of power, the total energy consumption per day would be 0.96 kWh. In contrast, in the proposed multi-perspective system, during the testing period, the water pump only ran for 4 hours according to the specified scenario, resulting in an energy consumption of only 0.32 kWh. Therefore, the energy savings achieved is approximately 60%.

CONCLUSION

The multi-perspective approach, utilizing both timing information and ambient light intensity conditions to regulate power activation within the aquaponic system, has demonstrated superior performance compared to mono-perspective methods relying solely on timing or light intensity. The primary strategy is time-based control, where power activation is disabled between 6 PM and 6 AM. This is complemented by an additional perspective through light intensity measurements during the active cycle of the system. If the natural sunlight intensity falls below a specified threshold, the water pump system can be deactivated since evaporation processes are minimal, eliminating the need for continuous irrigation. This approach optimizes electrical energy consumption by controlling the activation of the pump and artificial lighting system, ensuring plant growth lamps remain inactive during nighttime, emulating the natural photosynthesis cycle of plants.

For future research, integrating temperature and humidity sensors as additional perspectives could further enhance the accuracy of water pump activation during the day. This would address scenarios where light intensity is suboptimal, yet high ambient temperatures lead to increased evaporation rates, necessitating pump activation to maintain system balance.

REFERENCES

- Alam, M. N. H. Z., Kamaruddin, M. J., Samsudin, S. A., Othman, R., Radzi, N. H. M., Emmanuel, A. A., & Abidin, M. S. Z. (2023). Smart Farming Using A Solar Powered Aquaponics System For A Sustainable Food Production. *Malaysian Journal of Science*, 42(1), 68–77. DOI: 10.22452/mjs.vol42no1.7

- Amiruddin, N. F., & Fadlil, A. (2023). Real Time Clock (RTC) module based dance humanoid robot timer system. *Signal and Image Processing Letters*, 5(2), 1–8. DOI: 10.31763/simple.v5i2.56
- Arthy, E. a. R. (2023). Harvesting Intelligence: A Comprehensive Study on Transforming Aquaponic Agriculture with AI and IoT. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(8s), 782–795. DOI: 10.17762/ijritcc.v11i8s.9473
- Febriani, S. D. A., Alqarana, A. M., Wibowo, M. J., & Fahriannur, A. (2024). Assessing the Performance of Off-Grid Solar Photovoltaic Power Plants in Supporting Aquaponics Systems. *PENA TEKNIK Jurnal Ilmiah Ilmu-Ilmu Teknik*, 9(1), 54. DOI: 10.51557/pt_jiit.v9i1.2170
- Ghaffar, A., Abbas, A., Afzal, K., Batool, K., Nawaz, B., Zafar, L., Shaheen, H., Sajid, S. A., & Yasin, R. (2024). Innovations in Aquaponics Technology and Building Sustainable Infrastructure for Agriculture. *Indonesian Journal of Agriculture and Environmental Analytics*, 3(2), 121–134. DOI: 10.55927/ijaea.v3i2.11123
- Gillani, S., Abbasi, R., Martinez, P., & Ahmad, R. (2022). Review on Energy Efficient Artificial Illumination in Aquaponics. *Cleaner and Circular Bioeconomy*, 2, 100015. DOI: 10.1016/j.clcb.2022.100015
- Jaya, D. S., Styawati, S., & Syahirul, A. (2024). Automation of aquaponics systems through integration of RTC modules, turbidity sensors, and water level sensors. *Journal of Soft Computing Exploration*, 4(4), 262–275. DOI: 10.52465/josce.v4i4.267
- Karimanzira, D., & Rauschenbach, T. (2018). Optimal Utilization of Renewable Energy in Aquaponic Systems. *Energy and Power Engineering*, 10(06), 279–300. DOI: 10.4236/epe.2018.106018
- Kasiselvanathan, M., Prasad, J., & Sekar, G. (2022). Arduino UNO Controller and RTC-Based Medication Reminder and Monitoring System. In *Lecture notes in networks and systems* (pp. 199–204). DOI: 10.1007/978-981-19-0976-4_17
- Kolhapuri, S. B., Shenvi, S. V., Kulkarni, S. R., & Y, A. N. (2024). Survey Paper on “IoT-Driven Aquaponics for Sustainable Agriculture.” *IRO Journal on Sustainable Wireless Systems*, 6(1), 28–47. DOI: 10.36548/jsws.2024.1.003
- Mandl, S., & Ludwig, B. (2010). Multi-context Systems with Activation Rules. In *Lecture notes in computer science* (pp. 135–142). DOI: 10.1007/978-3-642-16111-7_15
- Neukirchner, M., Lampka, K., Quinton, S., & Ernst, R. (2013). Multi-mode monitoring for mixed-criticality real-time systems. *International Conference on Hardware/Software Codesign and System Synthesis*, 34. DOI: 10.5555/2555692.2555726
- Palippui, H. (2024). Optimising Energy Efficiency in Offshore Buildings: Supporting SDG 7 - Clean and Affordable Energy. *Maritime Park Journal of Maritime Technology and Society*, 147–152. DOI: 10.62012/mp.v3i3.41151
- Patil, A., G, M., & K, P. (2023). Automatic Street Light On and Off Using LDR. *International Journal for Research in Applied Science and Engineering Technology*, 11(5), 849–851. DOI: 10.22214/ijraset.2023.51617
- Pawar, M. (2022). RTC Based Power Control System. *Interantional Journal Of Scientific Research In Engineering And Management*, 06(03). DOI: 10.55041/ijrsrem11797
- Yuana, H., Wulansari, Z., & Chulkamdi, M. T. (2023). Automatic Plant Watering System Using RTC And Rain Sensor. *J-INTECH*, 11(2), 233–243. DOI: 10.32664/j-intech.v11i2.1101
- Zhang, L., Pei, J., Bai, K., Chen, Z., & Zhang, J. (2023). A Closed-Loop Multi-perspective Visual Servoing Approach with Reinforcement Learning. *2021 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, 30, 1–7. DOI: 10.1109/robio58561.2023.10354958