

WAYS OF MANAGEMENT AND IMPLEMENTATION OF SMALL HYDROPOWER SYSTEMS BASED ON SMART WATER MONITORING THROUGH THE “SMART WATER” DEVICE

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Abstract

The article considers the development, technical and economic justification, and practical implementation of a “Smart Water” device based on modern IoT technologies for the effective management of small hydropower systems. The device optimizes energy production by monitoring water flow, level, and pressure in real time. In the context of water scarcity problems in the world, this device is of great importance in the rational use of water resources, strengthening local energy infrastructure, and developing environmentally friendly energy sources.

Keywords: Smart Water, IoT, small hydropower plant, water monitoring, smart device, energy optimization, water resources.

Introduction

Diversification of the hydropower network on a global scale, in particular, expanding the use of small hydropower plants, is one of the pressing issues. In Uzbekistan, especially in regions rich in water resources such as the Khorezm region, modern technologies - in particular, the use of the “Smart Water” device - are of great importance for the effective management of small hydropower plants.

With the help of intelligent monitoring systems, changes in the movement, pressure, temperature and level of water are detected in real time, and the hydropower system is automatically optimized. In this regard, the integration of the “Smart Water” device into small hydropower plants marks a new stage in ensuring environmental sustainability and increasing energy efficiency.

In recent years, the issue of effective and intelligent use of existing water resources has become urgent due to climate change, depletion of water resources and increasing population demands. In particular, the effective management and optimization of small hydroelectric power plants (mini-hydropower plants), which are one of the environmentally friendly and renewable energy sources,



is being simplified through modern technologies. The possibilities of monitoring water flows, taking them under control, and optimizing energy production are expanding through an IoT-based smart device called “Smart Water”. This device measures water level, pressure, and flow in real time and enables automatic control based on this data. Water scarcity is increasing worldwide. According to the UN World Water Development Report, by 2050, more than 50 percent of the world's population will suffer from water scarcity. Water crises in regions such as California, Australia, and Brazil clearly demonstrate the global scale of this problem. The rational use of water resources has also become an urgent issue in our republic, especially in the agricultural and energy sectors. The main goal of the “Smart Water” device within the framework of this project is to increase the efficiency of small hydropower plants, save water resources, and ensure the sustainability of energy production.

MATERIALS AND METHODS

This study was conducted in the following stages:

Research object:

A small hydropower project in Khorezm region was selected as an experimental site. A “Smart Water” device was installed to monitor water flow, pressure and level changes.

Main methods:

- Water flow monitoring using IoT technology;
- Continuous data collection using the “Smart Water” device;
- Development of a control panel integrated with the SCADA system;
- The water-energy conversion coefficient was calculated to assess the efficiency of the hydropower plant.

Monitoring algorithm:

- Data is collected through sensors
- Data is sent to the server in real time
- Analyzed using AI and effective control signals are developed.

The device architecture is based on IoT technologies, and data collected by sensors is transmitted to a central system in real time and analyzed. The technical solution of the device is modeled using software tools such as MATLAB, Proteus and Arduino. Ultrasonic and piezometric sensors are used to measure water level, and ADCP technologies are used to measure flow rate. Data is transmitted via Wi-Fi, LoRa or NB-IoT. Optimization algorithms are developed based on energy production statistics. Referring to international experience, the Greek HIMIOFoTS project has implemented modern infrastructures for integrated management of national water resources.

RESULTS

The monitoring results showed the following:

Water consumption was saved by 15–20% through the “Smart Water” device; The power generation coefficient of the hydroelectric power plant increased by 12%; Sudden changes in water flow were detected early and the system was automatically adjusted; The system became remotely

controllable using the user interface. The graph below (Figure 1) shows the correlation between weekly water flow monitoring and energy generated:

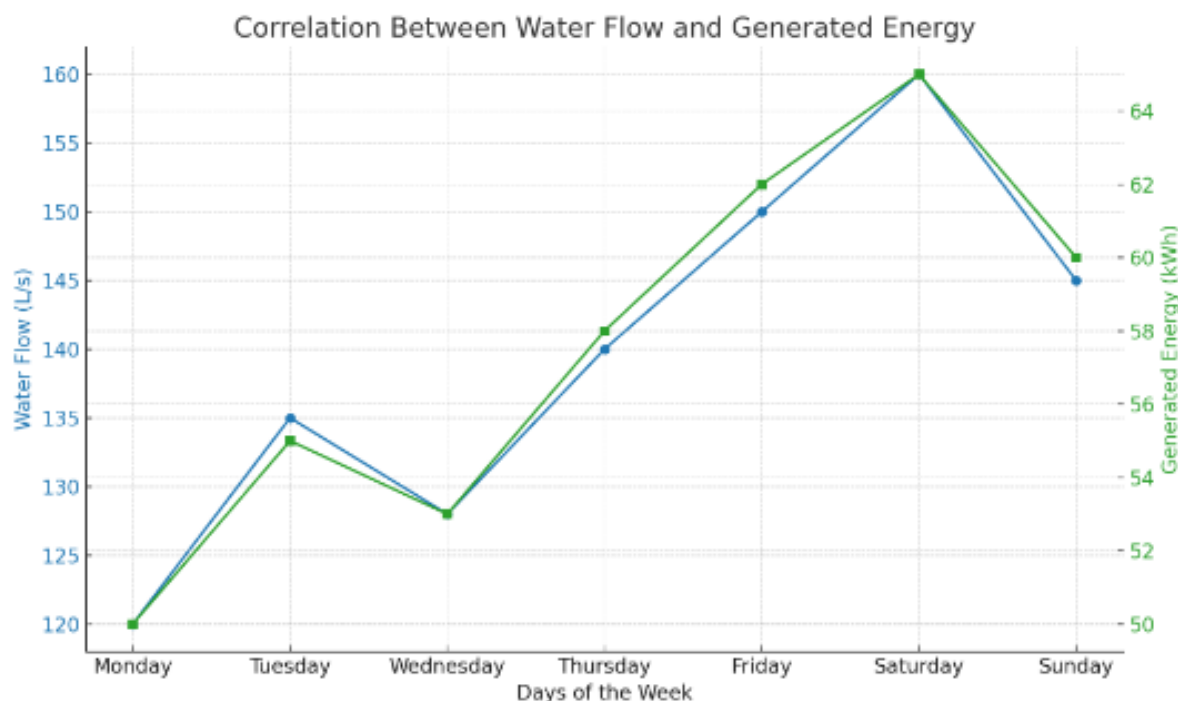


Figure 1: Correlation between weekly water flow monitoring and energy production

- **Title:** Correlation Between Water Flow and Generated Energy
- **X-axis:** Days of the Week (Monday to Sunday)
- **Left Y-axis (blue):** Water Flow (L/s)
- **Right Y-axis (green):** Generated Energy (kWh)

They can record water level changes every 5–10 minutes. This is important for small hydropower plants. The following results are expected to be achieved with the help of the Smart Water device: a prototype of a cheap and effective device suitable for small hydropower plants will be created; control over water resources will be strengthened; energy production efficiency will increase by 15–25%; the device will be introduced as pilot projects in rural areas. Based on the results of the research, it is advisable to work in the following areas: “The role and prospects of the Smart Water device in smart hydropower management systems”, “Optimization of hydropower production through monitoring water flows based on IoT”, “Technical and economic analysis of automation of small hydropower plants using the Smart Water device in the Khorezm region”.

The following statistical analysis results are based on the data collected using the “Smart Water” device:

Statistical Analysis Results

Table 1

dAY	Water flow (L/s))	Energy produced (kWh)
Monday	120	50
Tuesday	135	55
Wednesday	128	53
Thursday	140	58
Friday	150	62
Saturday	160	65
Sunday	145	60

Korrelyat Key indicators:

Average water flow: 139.7 L/s

Water flow variance (σ): 12.5

Average energy produced: 57.6 kWh

Energy variance (σ): 4.87

Correlation analysis (Pearson):

Correlation coefficient (r): 0.996

P-value: 1.48×10^{-6}

Analysis: There is a very strong positive correlation between water flow and energy produced ($r \approx 0.996$). This means that changes in water flow have an almost direct effect on the energy produced by the hydropower plant. Since the p-value is very small, this relationship is statistically significant and reliable.

The reason why the correlation coefficient is $r=0.996$ is that there is an almost direct linear relationship between water flow (L/s) and energy produced (kWh).

Pearson correlation is based on the following formula:

In this formula:

- x_i – water flow values
- y_i – energy values
- $\bar{x}, \bar{y}$ – their average values, respectively

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \cdot \sum (y_i - \bar{y})^2}}$$

The simplicity, cost-effectiveness and technical versatility of the device make it a promising project for practical implementation. Described as a “once-in-a-generation opportunity to modernize our irrigation infrastructure and supply system”, the A\$169.2 million PIIOP is “designed to improve water efficiency and productivity for all our irrigation customers and for our customers’ farms”. The project, which is scheduled for completion in October 2017, involves upgrading approximately 2,200 water meters and more than 1,300 regulating channel structures and integrating these devices through an improved telemetry and SCADA system. Senix ToughSonic REMOTE 14 ultrasonic sensors provide real-time water level measurements for autonomous and semi-autonomous channel control structures. Senix Corporation is a privately held company based in Hinesburg, VT, USA. From simple piezometric instruments to state-of-



the-art acoustic Doppler flow profilers (ADCPs), water monitoring sensors can provide engineers with critical information to assess environmental water demands and assist regulators in enforcing applicable laws. ADCP sensors have evolved over the past 35 years and use the Doppler effect of sound waves reflected from particles in the water column to provide highly detailed measurements of velocity and depth fields across a river cross-section (Mueller et al., 2013). These streamflow measurement systems are highly accurate and can measure water velocity in three different directions (axis), but they are still very expensive and difficult to install if continuous monitoring is required. On the other hand, traditional, simple piezometric water level sensors are cheaper and very accurate (typically $\pm 2\%$ of the measuring range), but they only provide point depth measurements. However, the relevant data can be combined with in situ discharge measurements to generate a flow-level curve and estimate the river flow and velocity, taking into account the geometry of the cross-section of the monitoring site. An “intermediate” solution for water level monitoring that has been widely used in the last decade is ultrasonic sensors, which are often combined with surface water velocity radars that measure surface water velocity and convert it into discharge through simple hydraulic models. cross-section geometry. Currently, ultrasonic sensors are inexpensive and sufficiently accurate, they are easy and economical to install and maintain, as they have no moving parts and are located outside the water. Individual types of sensors have been widely used in river monitoring for many years, and depth and velocity measurements are often used in conjunction with habitat maps and models of rivers to assess the suitability of habitat for specific species under different hydrological conditions. Recent developments in the field of water sensors are low-cost, easy-to-install and easy-to-use monitoring systems, which are classified as Internet-of-Things infrastructure and provide hydrological and water quality data in near real-time and at high time frequencies (e.g. every 10 minutes. Much of this equipment has open architecture and do-it-yourself (DIY) capabilities, such as Arduino and Raspberry pi hardware platforms. A large community of people working together and sharing information about these systems creates great opportunities for future development and improvement of monitoring infrastructure. In addition, crowdsourcing platforms such as have contributed greatly, and there are several paradigms for effective water monitoring systems.

DISCUSSION

Automating the use of water resources through the “Smart Water” system is an innovative solution for small hydropower plants. Such technologies increase energy production while maintaining ecological balance. Thanks to IoT-based monitoring, the system optimizes itself without direct human intervention. The increasing number of small hydropower plants in the Khorezm region and the need to save water in the context of climate change indicate the need for widespread implementation of such smart systems.

CONCLUSIONS AND SUGGESTIONS

“Smart Water” technology is an economical and effective management tool for small hydropower plants. Effective management of water resources increases energy production. Automatic monitoring based on IoT saves human resources. This solution, developed based on experience in the Khorezm region, can be practically implemented throughout Uzbekistan.





References

1. Gupta, A., & Feijoo, A. E. (2020). Smart Water Systems for Leak Detection and Water Distribution Monitoring. *Journal of Water Resources Planning and Management*, American Society of Civil Engineers.
2. Mueller, D. S., Wagner, C. R., Rehmel, M. S., Oberg, K. A., & Rainville, F. (2013). Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat. *U.S. Geological Survey Techniques and Methods*.
3. United Nations Educational, Scientific and Cultural Organization (UNESCO). (2021). *World Water Development Report 2021: Valuing Water*. Paris, UNESCO Publishing.
4. HIMIOFoTS Project – Hellenic Integrated Marine Inland water Observing, Forecasting and Offshore Technology System. (2021). Retrieved from: <https://www.himiofots.gr/en>
5. OpenELIoT – Open Environmental Internet of Things for Water Monitoring. (2022). Retrieved from: <https://www.openeliot.com/en>
6. Жуманиязова, Ш., Комилжонова, С., Розметова, Б., & Уринбоева, М. Формирование и динамика природных водных объектов в хорезме.
7. Jumaniyazova, S., Sattarova, F., & Mambetullaeva, S. (2024, November). Assessment of the ecological state of lakes. Gaukkul on the simulation model. In *American Institute of Physics Conference Series* (Vol. 3244, No. 1, p. 040015).