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AN INTERNET OF THINGS (IOT)SYSTEM FOR MONITORING AND CONTROLLING WATER DISTRIBUTION STATIONS IN REMOTE AREAS

Hany Mahany Ismaiel[1*],Ali Mahmoud Rashed[1],Rahouma Kamel Hussein[2],Ahmed Abd El-Aziz kolkila[1], Maha Medhat Hassan[1]

[1]Systems and Computers Engineering department AL-Azhar University, Cairo, Egypt

[2]Computer Science, Nahda University in Beni Suef, Beni Suef, Egypt

*Correspondence: hanymahany@gmail.com

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ABSTRACT

Equitable distribution of water in remote areas that lack a drinking water network or suffer from a scarcity of water [Matrouh, for example] is one of the vital demands that researchers have not paid sufficient attention to preserve the national water wealth and protect it from waste and theft. The strategy is for users with cars of different capacities. The operator of the water distribution station opens and closes the valve manually and records the quantities of water dispensed for each car. You notice that the amount of water dispensed from the amount of water produced differs greatly in increase and decrease, which required the necessity of creating an automated system using Internet of Things technology. The research presents a control and monitoring system for the operation of pure water distribution stations, with central monitoring of the quantities of discharged water. The valves are opened and closed automatically and the reading of meters measuring the amount of discharged water is transferred to the cloud network of the central monitoring unit.Aprototype was made in Matrouh Governorate in Egypt with the components Microcontroller atmega 2560, ESP 8266, electrical valve and, a flowmeter. The Eagle program was used to make the initial design of the (PCB) and the Arduino IDE program to write the codes. The system offers user-friendly functionality suitable for unskilled workers, boasts a cost-effective design compared to alternative like the SCADA system, and ensures that the entirety of produced water reaches its intended recipients. Previously undetermined water losses, resulting from the lack of control and theft facilitated by the illegal sale of contracted water quantities, have been mitigated significantly by the proposed system. Initial implementation showcased a commendable control level with a mere 1.7% error rate, further refined by introducing a variable delay in valve closing time (LAG) during initialization, resulting in an impressive 0.1% error rate with real-time monitoring.

KEYWORDS: flow meter sensor, IoT, water station, monitoring system, water losses control, remote areas, electrical valve, scada system, Hyper scada system.

نظام انترنت الأشياء للمراقبة والتحكم في محطات توزيع المياه في المناطق النائية

هاني مهني إسماعيل[1*]، علي محمود راشد[1]،رحومة كامل حسين[2]، أحمد عبد العزيز قلقيلة[1]، مها مدحت حسن[1]

[1]قسم النظم والحاسبات، كلية الهندسة، جامعة الأزهر، مدينة نصر، القاهرة، مصر.

[2]قسم علوم الحاسب، كلية الهندسة، جامعة النهضة، بني سويف

*البريد الاليكتروني للباحث الرئيسي : hanymahany@gmail.com

الملخص

يعد التوزيع العادل للمياه في المناطق النائية التي تفتقد الي شبكة المياه الشرب او تعاني من قلة المياه علي سبيل المثال - محافظة مرسي مطروح - من المطالب الحيوية التي لم يعرها الباحثون الاهتمام الكافي وذلك للحفاظ علي الثروة المائية الوطنية وحمايتها من الهدر والسرقة حيث يتم نقل المياه من الخزانات الاستراتيجية الي المستخدمين بسيارات ذات سعات مختلفة ويقوم عامل التشغيل بمحطة توزيع المياه بفتح وغلق المحبس يدويا وتدوين كميات المياه المنصرفة لكل سيارة . تلاحظ اختلاف كمية المياه المنصرفة عن كمية المياه المنتجة بالزيادة والنقصان بشكل كبير كما تلاحظ وجود شكاوي من المواطنين بان كمية المياه التي تصلهم ليست الكمية التي تم التعاقد عليها مما تطلب ضرورة عمل منظومة آلية باستخدام تقنية انترنت الأشياء . يقدم البحث نظام تحكم ومراقبة لتشغيل محطات توزيع المياه النقية مع وجود مراقبة مركزية لكميات المياه المنصرفة .يتم فتح وغلق الصمامات بشكل آلي ونقل قراءة عدادات قياس كمية المياه المنصرفة الي الشبكة السحابية (cloud network) لوحدة المراقبة المركزية مع الأخذ في الاعتبار كمية المياه المنصرفة اثناء غلق المحبس وقد تم عمل نموذج أولي في - محافظة مطروح- بمصر بمكونات رئيسية (Micro controller atmega 2560-ESP 8266 -محبس كهربائي -جهاز قياس تصرف) مستخدما برنامج Eagle -لعمل التصميم الاولي للدائرة الالكترونية (PCB)وبرنامج Arduino IDE لكتابة وعليه فان النظام سهل الاستخدام من قبل العاملين غير ذوي الخبرة ،أقل في التكلفة من انظمة التحكم الاخري مثل (SCADA System)، يضمن وصول كمية المياه كاملة الي مستحقيها بعد ان كانت نسبة فقد المواطن للمياه غير معروفة لغياب الرقابة وسهولة السرقة من خلال عدم ملئ السيارات بالكميه المتعاقد عليها ثم بيعها في السوق السوداء، فقد قدم النظام رقابة كاملة وحقق نتائج أولية بنسبة خطأ ١.٧ ٪ ثم تم تحسين هذه النسبة باضافة عنصر تأخير وقت غلق المحبس (LAG) ضمن عملية التهيئة وجعله متغيرا لتصبح ٠.١ ٪ مع مراقبة لحظية لكل سيارة يتم ملؤها من خلال محاكاة واقعية وتقارير تظهر رقم السيارة ،وقت تحميل المياه وكمية المياه الفعلية التي تم تحميلها من خلال انترنت الاشياء

الكلمات المفتاحية: حساس قياس التدفق، محطات المياه، نظام مراقبة، التحكم في المياه المهدره، المناطق النائية، محبس كهربائي، انترنت الأشياء، نظام سكادا، نظام هايبر سكادا.

INTRODUCTION

Water is an important natural resource that should be used more efficiently. Remote areas where water networks aren't available usually suffer from a lack of efficient water monitoring and distribution systems. In these areas, the problem of water waste or even theft of quantities of water arises due to the lack of live monitoring and control of the actual amount of water consumed by the station. The main three goals of this paper are as follows, create a control and monitoring system for the water distribution station, use IoT techniques to monitor discharged water quantities, and the third goal is to record the discharged water quantities to a cloud network to ensure availability and sustainable management of water and sanitation for all [1].

The closest works related to this research in [2] proposed an IoT-based water control system that measured water levels in real-time. In this model, a sensor for measuring water level was used to detect water levels; when a certain level of water is reached, a signal is sent to a social media platform such as Twitter, and the data of the water level is displayed through a remote dashboard [3]. Suggests a water quality monitoring system that provides information about the nature of water over the Internet. The authors use an Arduino in addition to a pH sensor and a turbidity sensor, and data is sent via a Wi-Fi module that is used to transmit data to a webpage. Another water system was introduced in [4]. The authors implement a system that measures water quality and also determines the water level. The PH value and the water temperature were monitored, whereas the water level system measures the water level in the tanks. The user can view all the values through the IoT, and the water pumps can be turned on from the IoT dashboard. In [5] the system precisely measures the amount of water delivered from the water station to the remote citizen houses where water networks are unavailable. The proposed system uses an AVR ATmega2560 remote citizen, a keypad, a liquid crystal display, and an internal memory. Another area of research is illustrated in [6], where the system can be easily installed. Flow sensors are installed in pipes and continuously report the water quantity to the server in real-time. This data will be updated on a cloud and the user can visualize the water level on a smartphone connected to the internet. The Internet of Things (IoT) is a rapidly expanding computer trend that enables objects or gadgets linked to the Internet to have the ability to gather, process, and share information [7]. The "Internet of Things" is known as a technology that has demonstrated its existence as a network of machines or gadgets that can communicate with one another [8,9,10,11]. Take urgent action to combat climate change and its impacts[12]. In remote areas, water distribution is done through trucks that transfer water from the main or sub-stations to homes. In such areas, water networks are not available. Examples of these areas are the remote areas in Egypt far enough from the Nile River and the areas in Saudi Arabia where people depend on groundwater. Those areas suffer from several problems such as poor management of water resources and a lack of efficient systems for water monitoring and distribution. In addition to that problem, the distribution processes are done by people who do not have any education or training in using the automated distribution systems. This results in the difficulty of collecting and analyzing data. Hence, the proposed system had to be simple to be easily run and used by those operators for better water resource management. Many studies presented water quality monitoring systems [13], but only a few discussed the problems related to areas, that lack water networks, to which water is transported from stations via wagons. In this paper, a simple system for water distribution is proposed and implemented. The idea of the system is to measure and control the quantity of water supplied to the customer tank. Once the operator enters the required quantity, the system generates a signal to start its task. It sends a signal to the valve through the relay [14] to open to allow the water to pass to the customer tank. A flow meter is used to send an electric signal to indicate the water flow quantity. The water quantity is then calculated. When the needed quantity of water is reached, the system sends a signal to the valve to stop the flow. The measured quantity of water is sent to an LCD and a storage medium for later analysis. Such data would be available for simulation and reporting over time. Before going into operation mode, the system needs a simple configuration, including IoT settings and system settings. In the IoT settings, the administrator configures the DNS, the vehicle channel, and the quantity. The system settings include the number of liters per pulse, opening time, closing time, lag quantity during the opening and closing operation, and the flow meter's initial quantity. The rest of the paper is organized as follows: Section (2.2.1) gives details on the proposed system block diagram and flowchart, while the system hardware components and the mathematical equations are given in section(2.3) and section (2.4) respectively. Section (3) presents results and discussions. Conclusions, future work, and references are given in the End of the paper.

2. MATRIALS AND METHODOS

2.1. Study Area

The following section shows the location of the water station where the project was implemented. The station is Al kasr distribution station, which is located in a remote area near Egypt's western border, see Figure 1 [15].

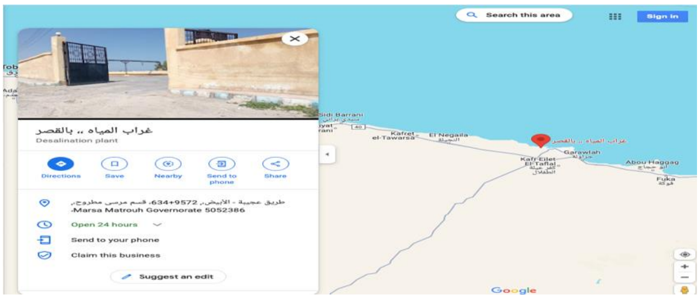


Fig.1. Elkaser distribution station location in Marsa Matrouh, Egypt

2.2. The Proposed System

The proposed system consists of hardware and software. The hardware used the Eagle software for PCB design, while the software in the proposed system is divided into two branches. The first one includes the software of the microcontroller, by Arduino Language Programming (ALP). The ALP language consists of C & C++ for Embedded system applications. The second branch is the web application software to receives data from sensors and presents it on the web application for users who have access to the system by a username and a password. The prototype relied on a trial version of the software (HYPER SCADA SYSTEM), in the proposed system.

2.2.1. The proposed System Block Diagram And Algorithm

The block diagram of the proposed IoT-based water monitoring system is illustrated in **Fig 2.**

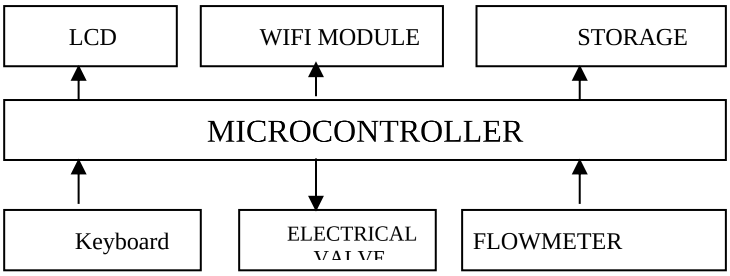


Fig.2. The proposed IoT-based water monitoring system block diagram

At the startup of the system operation, there are two paths: one for the administrator and the other for normal operators. In the administration path, the admin selects one of two options; the first one is "IoT settings" where the admin determines the Domain Name System (DNS) and the target channels. The second option is in "the system setting" with three parameters that can be configured (the lag of valve closing, valve opening-closing time, and the number of liters per pulse). The purpose of controlling these parameters by the admin is to make the system more flexible and increase the accuracy of the system in determining the amount of the transferred water to the water carts and to reduce the amount of wasted water. This is one of the novel features of the proposed system. Another important feature is recording each cart ID and the related amount of the transferred water on the Storage device (SD) [16] to ensure that water reaches its beneficiaries and to easily link the proposed system to the institution's financial system through the vehicle number. In both paths, administration or normal water transferring the entered password is validated and the system checks for an SD to prevent any unofficial operations to transfer water in the event of failure to upload data through the IoT system. While in the operator path, the system allows the operator to enter the value of the needed water quantity to be delivered to the customer cart. Once it receives the "Start" signal, the system sends a signal to a relay that opens the valve of the water. A signal from the flow meter that indicates the quantity of water pumped to the customer, the algorithm of the system is shown by flow chart in Figure 3. The operation of the system can be accurately illustrated through the following algorithm :

Start the system (turn it on)
Configure system settings by login through the password
If (the password matching admin user)
{
Select System Setting OR IOT Settings

```
        If (System Setting)
                    {
                    Enter the number from 1 to 4
                If (number =1)
                    enter the number of litters per pulse
              else If (number =2)
                    enter valve opening time
              else If (number =3)
                    enter valve closing time
              else If (number =4)
                    Define lag of quantity
              }
           Else ( IOT settings )              Select DNS OR Channel
              {
                If ( number =1)
                          Enter  DNS
              else if (Channel)
                    {
                    Enter numbers from 1 to 3
                          If (number =1)
                                Enter the Vehicle channel then save
                          else If (number =2)
                                Enter quantity channel then Save
                          else If (number =3)
                                Enter Total channel then Save
                          }
              }
        }
  Else (the password matching an operator     password)
        {
        Check SD
        If (SD state = 0)  /* SD not Detected */
              Connect the SD
        Else
              Please choose the correct number from 1:3
        Enter the vehicle ID
        Save the vehicle ID
        Enter the quantity
        If (Wanted quantity < (Resent quantity +lag quantity) & Stop button LOW)

        Open the valve and recalculate after every pulse
        Else
              Close the valve
           Save all the data on the SD
        Send the data to the cloud
        Enter the next vehicle ID & new quantity
```

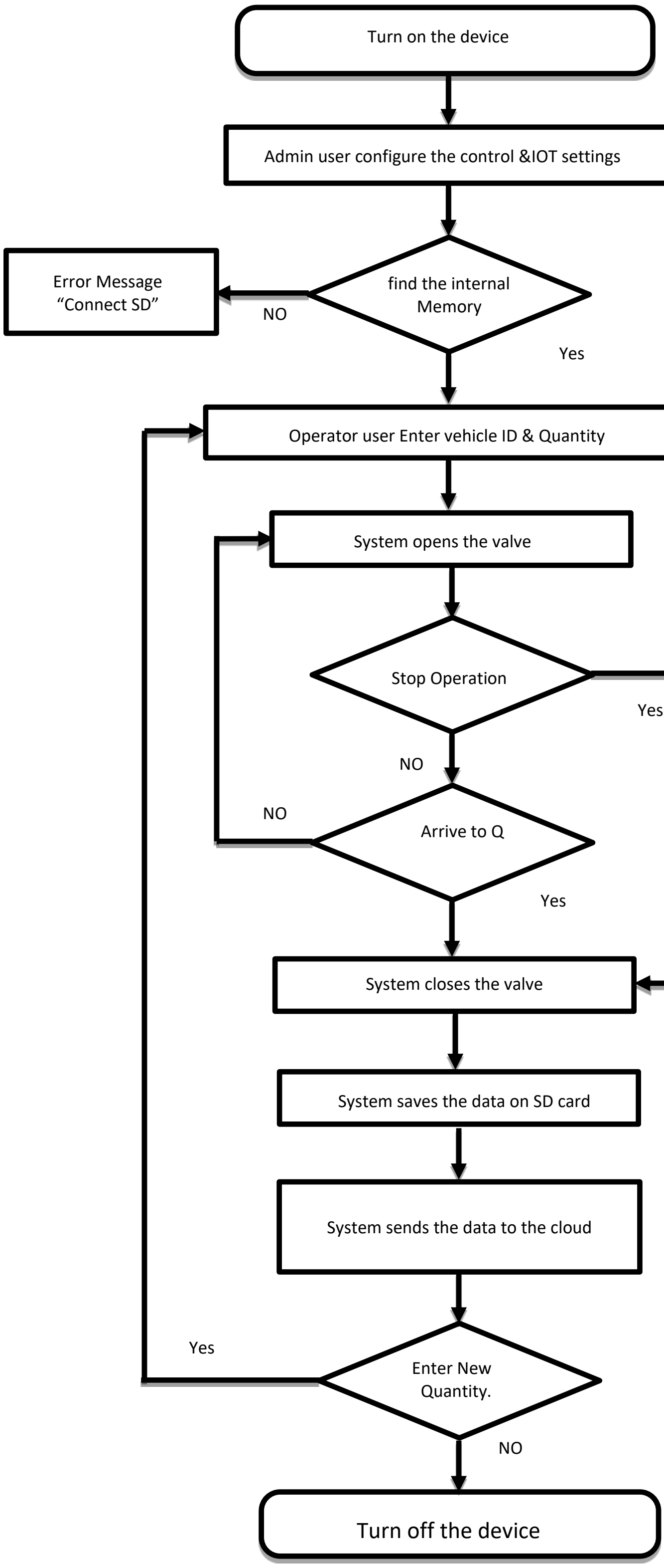


Fig.3. Flowchart diagram of the system

2.3.The Proposed System Hardware Components

In Egypt – Mursa Matrouh – Elkaser Station the proto-type of the proposed system has been implemented. Fig.3 shows the PCB of the whole system hardware design. The ATMEGA 2560 is used to control the whole system. It can be programmed using the C & C++ language and possesses the main components of an integrated circuit chip. The ATMEGA checks the flow rate and the volume of water passing through a pipe. This microcontroller is the AVR type, produced by the Atmel firm. The device can read the input from the flow-meter sensor, process the program, and control the valve based on the entered water quantity. In this research, a novel utilization of IoT technology based on Atmega2560 and ESP 8266 for the full Control and sending the Data to the cloud.

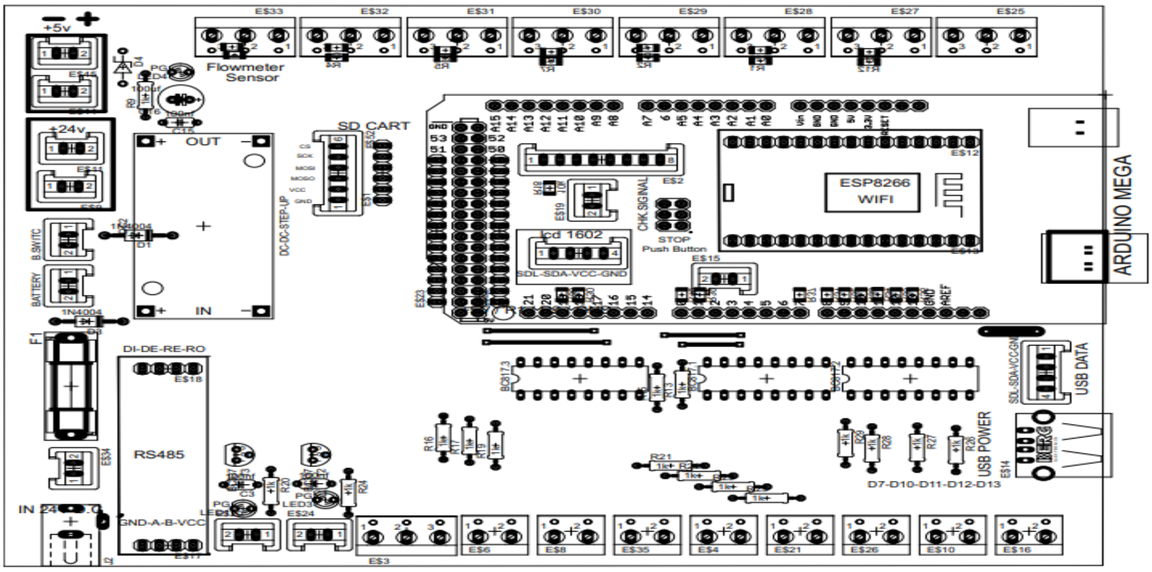


Fig.4. The PCB of the system hardware design

2.3.1 Power supply and Backup battery

The ATMEGA 2560, ESP8266, Liquid Crystal Display (LCD), SD CARD, and solid-state Relay operate on 5V DC. The step-down DC-DC converter is used in the PCB to regulate voltage and protect the circuit. The system uses a 10000 mA (Milliamperes) backup battery to life system around 4 hours when the AC source is disabled.

2.3.2 Microcontroller Aatmega 2560

Microcontroller atmega 2560 in Arduino mega module is a digital I/O Pins 54 (of which 15 provide PWM output), Analog Input Pins 16, Clock Speed 16 MHz, SRAM 8 KB, EEPROM 4 KB. The proposed system uses one digital pin for the flow-meter pulse, one digital pin for control, two digital pins for the l2C module, one digital pin for the WIFI module, and two digital pins for the keyboard[17].

2.3.3. Node MCU ESP8266

Node MCU ESP8266 is the mediator between the microcontroller and the web. It is configured by AT Command. After plugging in with Arduino IDE and selecting the Port and bud rate, write this command to configure the module. The data will be transmitted from the microcontroller to ESP8266 via hard serial "TX microcontroller" with "RX NodMCU".

"AT+OK " to check the response.
"AT+CWLAP" to discover available networks.
"AT+CWJAP" to connect the network via said and Password.

2.3.4 Electrical valve model

The Electrical Valve Model PSR-E50, with a maximum torque of 50 Nm, is employed in our system. This specific torque type utilizes a gearbox powered by alternating current (AC). To efficiently regulate the AC power with direct current (DC), a solid-state relay is employed.Noteworthy is the internal protection mechanism within the valve that automatically disconnects power to the motor upon reaching the fully opened or closed positions. In addition to this inherent protection feature, an extra layer of safeguarding is integrated into the proposal system. Here, the system administrator is granted the flexibility to configure the valve's operation by specifying both the opening and closing times. This dual protection setup enhances the overall safety and control of the valve within our system.

2.3.5. Electromagnetic flow-meter

An electromagnetic flow meter measures the flow rate of conductive fluids. A duty cycle of 50% means the meter's output signal is active for half the time and inactive for the other half. It is useful for applications that require on-off signal control. Specifics may vary based on the manufacturer and model. The flow meter is used in our system so that each pulse is an expression for a specific number of liters.

2.4. Equations and mathematical calculations

In this section, the mathematical calculations are presented. Equations 1 and 2 illustrate how the controller computes the difference between the needed quantity and the pumped quantity of water. Then equation 3 shows how the optimal amount of lag factor is calculated to improve the results and reduce the error rate.

The controller computes the difference between the needed quantity and the pumped quantity of water

$$Wd = Wn - Wp \quad \text{Eq. 1}$$

Where Wd is water difference, Wn is water needed and Wp is water pumped.

The delivered quantity of water is calculated by equation (2).

$$Q = N*PPL \quad \text{Eq.2}$$

Where Q is the quantity, N is the number of pulses generated from the flow meter and PPL is the pulse per liter.

When the reference reaches zero considering the closing period, the system sends a "Stop" signal to the relay that closes the valve of the water pump. The water quantity is stored on SD and sent to the cloud. At the end of the water transfer process, the system shows the total water quantity. The operator can close the valve by “STOP BUTTON” if the volume of carts is smaller than the quantity that the operator has entered to avoid the overflow.Through monitoring cars with a capacity of 10,000 liters (which is the most common case in this station used as a prototype), it was found that the filling time is variable due to the station’s reliance on an upper tank. The amount of water in the upper tank is an influential element in the water pressure and flow quantity.To calculate the optimal amount of lag factor, we calculated the approximate time needed to fill the car per second, then we divided the amount by the approximate time to get the amount of water that passes during one second, and then multiplied this amount by the number of seconds needed to close the valve and obtained the approximate amount and improved it after that. By trial and error as in Table 4; The actual data used in the first model is shown in Table 2 And The error ratio is calculated by equation (3).

$$\text{Error ratio } \% = (OV-Pr)/OV)*100 \quad \text{Eq.3}$$

Where OV is the Operator Value and Pr is the Proposal system reading.

3. RESULT AND DISCUSSION

This section discusses three topics, the Error Ratio before adding the “lag” parameter, improving the results to reach the smallest possible difference between the data calculated and transmitted by the proposed system and the data entered by the operator by adding the “ lag” parameter to configuration manue and making comparison between the proposed system and Supervisory Control and Data Acquisition (SCADA) system at another station to show the cost difference, which clearly shows how to reduce the cost through the proposed system.

3.1 The Error Ratio Before Adding “lag” Parameter

The numbers related to the initialization process were added from the manual for the flowmeter and the valve [18,19] taking into account some minor changes that differ from one station to another, such as changing the time for closing and opening the valve from the catalog from 16 seconds to 15 seconds. Accordingly, the time for opening and closing the valve was added to the element's configuration. Table 2 shows the configuration parameters of the proposed system.

Table 2 The system parameters for (Elkasr station-Matrouh)

Opening time configuration	15 second
Closing time	15 second
Flow-meter pulse signal	10 liters per pulse
Lag Quantity	170

Table 3 shows the results of five cases, where five different quantities of water in liters are entered by the operator. These quantities are given by samples 1 to 5. The actual amount of the transferred water to the water carts is then calculated.

Table 3 Ideal and actual water quantities with the error ratio before applying lag parameter

Parameters	Case1	Case2	Case3	Case4	Case 5
Operator Q (liters)	1000	4000	5000	6000	10000
*Calculated Q= N *PPL*	1170	4160	5160	6170	10170
Flow Meter	1170	4160	5160	6170	10170
Number of litter error	170	160	160	170	170
Error ratio = (OV-Pr)/OV%	17%	4%	3.2%	2.8%	1.70%

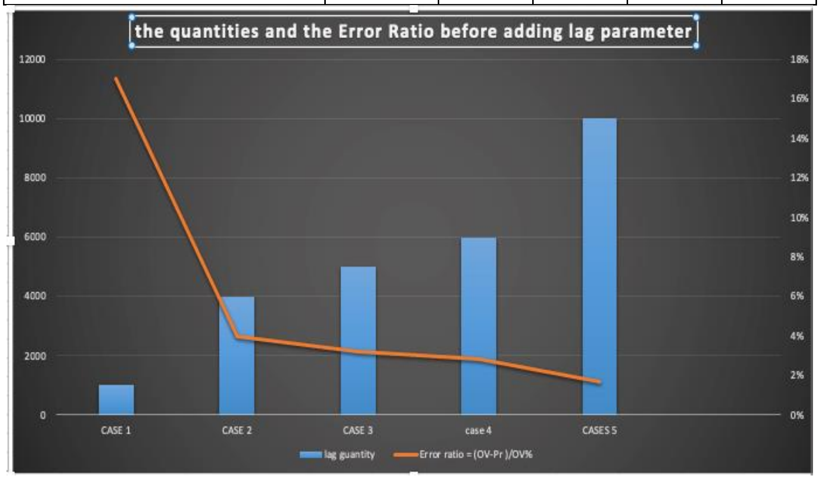


chart 1 The error ratio for the five different cases before using the lag parameter

3.2. Improving The Results By Adding " Lag " Parameter To Configuration

In this section, we will focus on case five (10000 liters) as it is considered the most common case in this water station. The lag parameter has been added to the proposed system that can be changed by the admin user from the configuration mode. The results are illustrated and discussed according to a real-time implementation of the proposed system considering the used parameters of the actual valve as shown in Table 4. The physical environment is represented in the proposed system hardware, the pulse signal generator yields a signal that is equivalent to the flow-meter pulse signal.

3.2.1 The Effect of lag On The Error Rate

To improve the results by using the LAG factor for the same amount with trial and error until the smallest possible difference between the amount of water required and the amount of water passed is reached. Thus, the lowest possible error rate for this proposed system is 0.1% under the lag factor shown in Table 4, so the optimal case is case 5D.

Table 4 Ideal and actual water quantities after adding a lag parameter

Parameters	Case5 A	Case5 B	Case5 C	Case5 D	Case 5 E	Case 5 F
Operator Q (liters)	10000	10000	10000	10000	10000	10000
*Calculated Q= N *PPL*	1170	10030	10020	10010	9980	9970
Flow Meter	1170	10030	5160	10010	9980	9970
Lag quantity	0	125	160	**170**	180	190
Number of litter error	170	30	20	10	20	30
Error ratio = (OV-Pr)/OV% (+ or -)	1.7%	0.3%	0.2%	**0.1%**	0.2%	0.3%

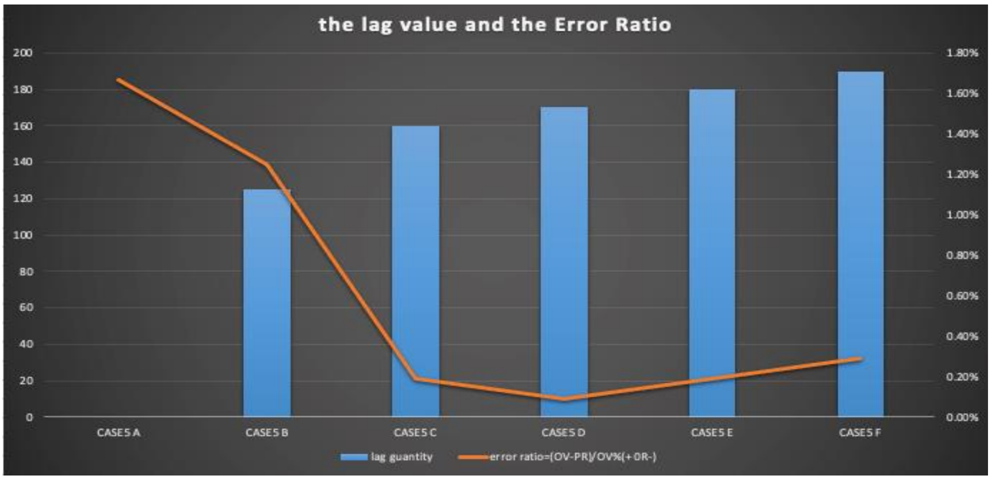


Chart 2 the relation between the lag value and the Error ratio

These results that were presented were observed to change in value by slight percentages each time, and this is due to The error ratio is not fixed because of valve lag quantity is not fixed. This is because the pressure causing the water flow is not constant at all times due to the increase and decrease in the amount of water in the upper tank. The results show that the system controls the opening and closing of the valve properly according to the required water quantity entered by the operator. Results show also that the system is making true adjustments based on the accepted error ratio in the water application.

3.2.2 the Error Ratio In The Quantity After Lag Parameter

In this section, we will use the results that appeared in the previous section, which show the best value for lag, which is the one that appeared in column case 5 D, to use it in different quantities and show the behavior of the system before and after improving the error rate by adjusting the value of lag when it turns out that the behavior of the error rates as it is decreasing. By increasing the quantity, it appears that the lowest error value was 1.67% at the quantity of 1000 liters before adding the lag value, and after using the lag value, the lowest error value was 0.09% at the quantity of 1000 liters.

Table 5 Ideal and actual water quantities with the error ratio after applying lag parameter

Parameters	Case1	Case2	Case3	Case4	Case 5
Operator Q (liters)	1000	4000	5000	6000	10000
*Calculated Q= N *PPL*	1010	4010	5010	6010	10010
Flow Meter	1010	4010	5010	6010	10010
Number of litter error	10	10	10	10	10
*Error ratio = (OV-Pr)/OV)*100*	0.1%	0.25%	0.2	0.166	0.1

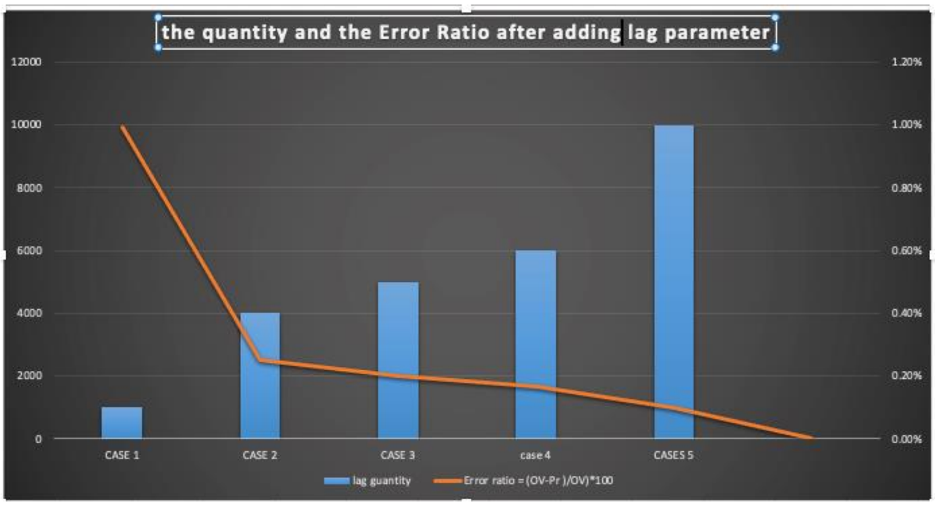


chart 3 The error and the multiple quantities after using the lag parameter

Also, the system is making a true backup and saving it locally on SD cards, and the water quantity is being sent to the website. The IoT configuration is shown in **Table 6.**

Table 6 The IoT system configuration

DNS	197.134.251.84
vehicle ID channel	501
Filled actual quantity channel	503

3.2 Implemented System

Fig. 5 shows how the operator enters the car number and the required quantity through this plate so that the system automatically completes the process. After successfully processing the data accurately and transferring it to the cloud, the operating process can be simulated as shown in Figure 6. The necessary reports can be shown to detect any rates of deviation from the expected curve as shown in Figure 7.

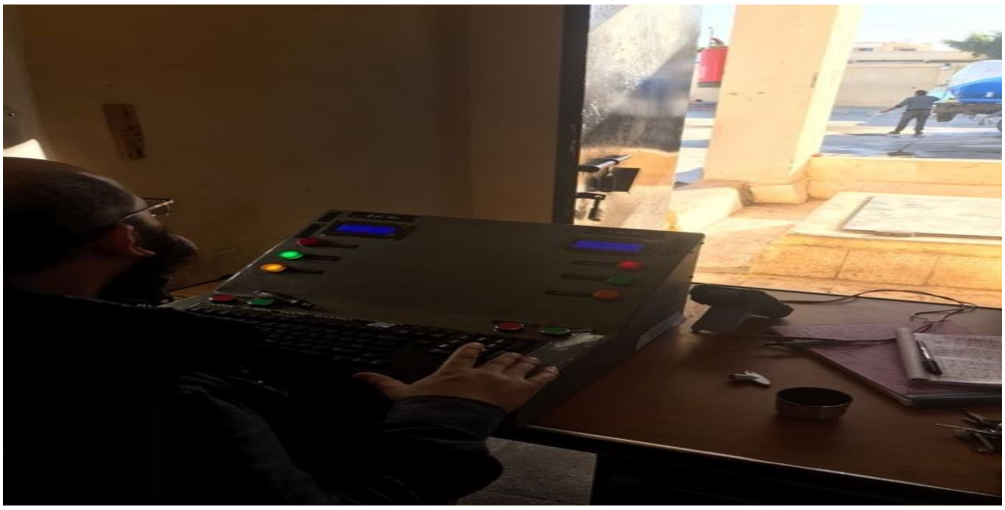


Fig.5. Operation phase (system after implementation)

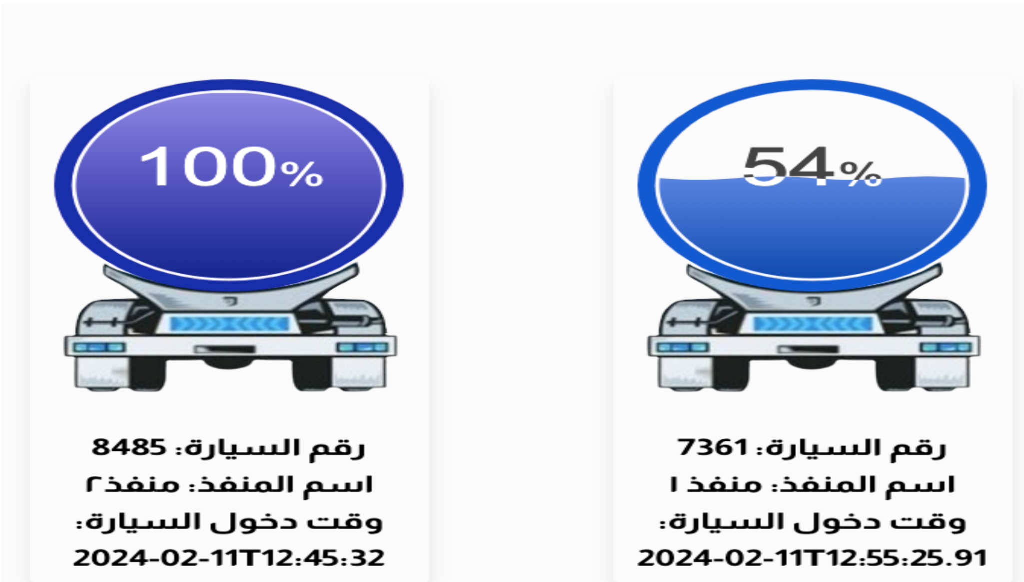


Fig.6. Real-time Simulation of Implemented System Through Web Application in the Management Phase

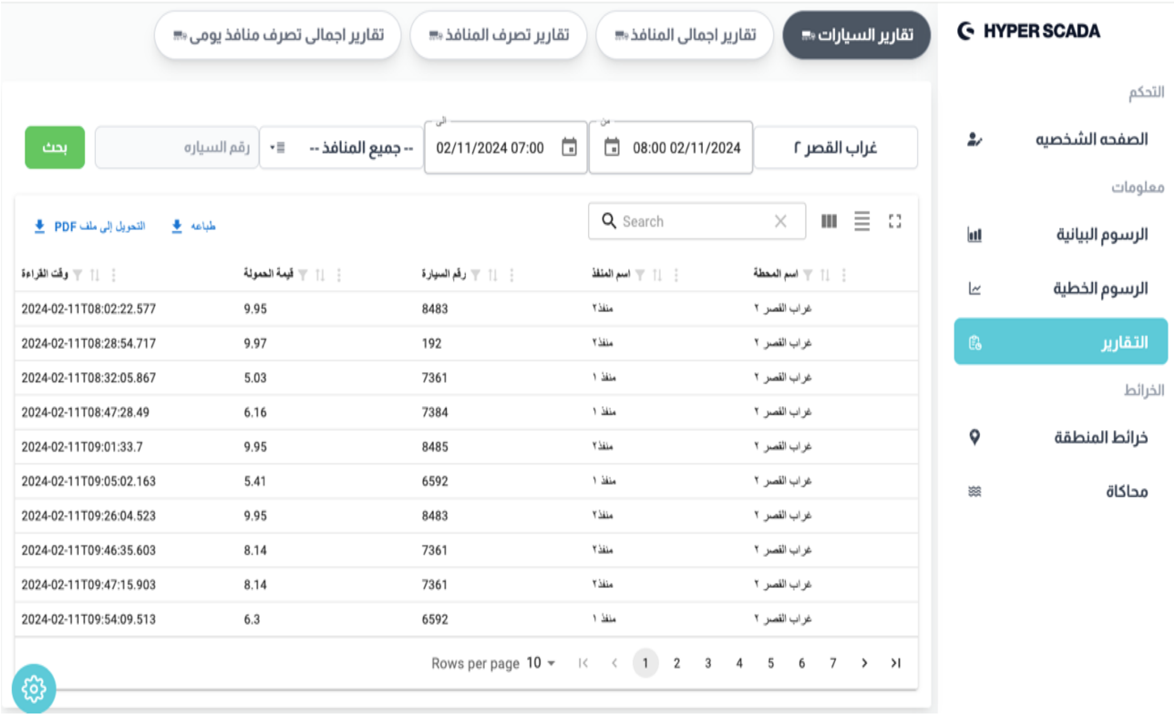


Fig.7. Statistical Reports within the Web Application during the Management Phase

3.3. Comparison Between SCADA And The Proposed System

The tangible benefits of the proposed system become evident through a comparative analysis with alternative systems, such as the SCADA system. Refer to Table 7 for a detailed presentation of the comparison results

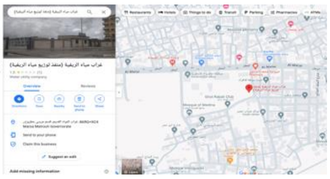
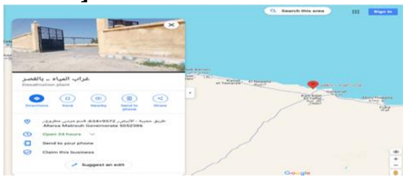
Location and map	**SCADA system in [Elrefea distribution station [20]** 	**Proposed system OR Hyper SCADA System in [El-Kaser Distribution station]** 
Controller	PLC Nedding programming	The proposed device (H-SB)just needs configuration
Using a Computer with special specifications and specialists in the operation phase	Yes	There is no computer in the operating place and anyone can enter the car number and quantity without any special work, such as rebooting the computer in case the problem occurs to the computer. These are the most important features of the system, especially in remote areas that are often poor and lack specialized education.
Sending data to the website	NO	Yes throw IOT
Support reports, charts, and simulations.	Yes locally in the station	Yes remotely in any place through user and password
Installation cost	Have cost for plc programming.	There is no PLC, NO programming just configuration forHS-B Device
Operation cost	High cost due to the need for specialized	Low cost due to no need for specializers in the operating process
The possibility of technical problems occurring during the operation process	High-due to using CISC architecture (complex instruction set computers) as computer	LOW – due to using RISC architecture (reduced instruction set computers) as a calculator
The percentage of water wasted or stolen is approximately	unknown	0.1%
Total cost	1- Installation plc programming 2- Operation cost 3- Maintenance cost	1- Less than the SCADA system due to no programming -Just configuration. 2- Less than the SCADA system due to no specialist for the operation Phase. 3- Less than the SCADA system due to using RISC architecture in the operation Phase.

Table 7 Comparison between SCADA System and proposed System (Hyper SCADA).

Conclusion

The advent of the internet and related technologies has presented an unprecedented opportunity to monitor and quantify water consumption in remote water stations like Matrouh

Water Station in Egypt. The Internet of Things (IoT) emerges as the key enabler for this remote monitoring capability, fostering seamless communication and data sharing among machines and electronic devices within a network.

This paper explores the design and implementation of a cost-effective system utilizing IoT technology for monitoring water quantity. Tailored for deployment in water companies operating in remote areas where traditional water networks are unavailable or there is a high reliance on groundwater, the proposed system serves as an efficient alternative. In Matrouh, Egypt, we successfully built and tested an IoT-based water monitoring and automatic cart filling system, offering a viable solution that overcomes the complexity and high costs associated with traditional SCADA systems.

Beyond cost-effectiveness, our system facilitates real-time analysis of water consumption by providing online statistics accessible from anywhere. Leveraging sensors, data is transmitted to a cloud, making it available at any time and location. This not only enhances ease of use, particularly for less experienced personnel but also ensures accountability by addressing issues of water loss and potential theft, a concern exacerbated by unauthorized water filling and subsequent black-market sales.

The implemented system has demonstrated its efficacy with initial results boasting an impressive error rate of 1.7%. Further refinement was achieved by incorporating a delay element in the valve closing time (LAG) during the initialization process, reducing the error rate to a remarkable 0.1%. Real-time monitoring of each filled car is conducted through a realistic simulation, generating comprehensive reports detailing the car number, water loading time, and the precise amount of water loaded, all made possible through the implementation of the Internet of Things.

Future work can be done to increase the features of the proposed implemented system with a more advanced function using artificial intelligence to open and close the valve automatically. This is done by Recognizing the car number and linking it to the car's tank capacity in the database. This is done by installing a Camera to Recognize the car number to open and close the valve automatically and thus the complete operation process is completed Without human intervention, using artificial intelligence.

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