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DESIGN OF A SIMPLE MONITORING SYSTEM FOR WATER DISTRIBUTION STATIONS AND COMPANIES

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Abstract

This paper aims to accurately measure the amount of delivered water from the water-station to the remote citizen houses, where the water networks are not available. A simple design is proposed. A non-experienced operator can run and use it. The proposed system has been applied in the water station of Matrouh governorate This water company used to have a waste quantity of water 44000 m^3 monthly. By applying the proposed simple system waste water is reduced to null. The proposed system uses an AVR ATmiga2560 arduino, a keypad, a laser crystal display (LCD) and an internal memory. The idea is that the operator starts the system and enters the quantity of needed water and then, a signal is sent to the arduino which sends a signal to the electro-hydraulic valve to open. The water flows into the customer tank. The flow meter sends an electric signal to arduino indicating the water speed. The arduino calculates the water quantity delivered to the tank and its price. When the needed quantity of water is reached, the arduino sends a signal to the valve to stop. The quantity of supplied water and price are sent to an LCD and a storage medium for simulation and reports. The proposed system is very cheap, easy to use and effective. It can replace the SCADA systems.

Keywords*:* Water-monitoring system, Flow meter, SCADA, Remote areas.

1. Introduction

Water is an important natural resource that should be used more efficiently. In the daily routine system, users are supposed to quantity of the water has been moved from company station tanks to the citizen houses. Conservation of water in remote areas and poor in water resources is done through designing and implementing an integrated system. This system ensures fair water distribution in remote areas using the supervisory control system (SCADA) to collect and analyze data. With the economies of poor countries, it may be hard to have the good design, implementation and operation and thus to collect and analyze data about water distribution. Added to that, there is a fact that the workers operating the water distribution systems are not holders of degrees in engineering or Internet of things (IOT) technology [1].

These conditions made it necessary to think about simple systems that can be easily run and used by these operators. This is the aim of the present paper. A simple system for water distribution is proposed. It utilizes the AVR ATMEGA 2560 arduino, a flow meter, a keypad, a water valve, and an LCD.

The proposed system has been applied in the water station of Matrouh governorate. In this area, water network is not available. Therefore, water is distributed from the water company to the customer's houses in tanks. During the process of filling in the tanks and distributing the water onto the houses, there were big amounts of water waste. The company could report that every month it used to have 44000 m^3 of waste water. After installing the proposed system, the quantity of this waste water has reached null.

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The idea of the system is that the operator starts the system and enters the quantity of water to supply to the customer tank. Once the operator presses enter, the arduino receives a signal to start its task. It sends a signal to the valve to open to allow the waster to pass to the customer tank. The flow meter sends an electric signal to arduino to indicate the water speed. The arduino calculates the water quantity supplied to the tank and the corresponding price. When the needed quantity of water is reached, the arduino sends a signal to the valve to stop. The final quantity of supplied water is sent to the LCD and a storage medium for later analysis. Such information would be available for simulation and reports over periods of time.

1.1 Related Work

Supervisory control and data acquisition (SCADA) [2] is a system of software and hardware elements that allows industrial organizations to control industrial processes locally or at remote locations, Monitor, gather, and process real-time data. SCADA also provide direct interaction with devices such as sensors, valves, pumps, motors, and human-machine interface (HMI) software. Finally, it records events into a log file.

SCADA systems are crucial for industrial organizations since they help to maintain efficiency, process data for smarter decisions, and communicate system issues to help mitigate down time. In the field of water monitoring and resources management, much scientific research has been presented. In [3], a structured methodology for optimizing SCADA systems from a life cycle perspective for the specific case of waste-water treatment units is proposed. The methodology embeds techniques for handling entropy in the design process and to assist engineers in designing effective solutions in a space with multiple constrains and conflicts.

In [4], a design of SCADA water resource management control center, by a bi-objective redundancy allocation problem and particle swarm optimization, has been illustrated and discussed. A bi-objective redundancy allocation problem (RAP) is proposed to design Tehran′s SCADA water resource management control center. Reliability maximization and cost minimization are also considered.

In [5], authors presented a water research management system survey in Egypt. Authors, in [6], present an IOT based water supply monitoring and controlling system with theft identification. an automatic water distribution system using ARM controller, is also presented in [7]. Authors, in [8], present an automatic water level controller with short messaging service (SMS). In [9], authors introduced a logical water level control system. Also, an automatic control system for water distribution is presented in [10]. Authors, in [11], introduced an automatic level indicator and controller to control the water level of an overhead tank [11]. A design and implementation, of an automatic audible water level controller by incorporating a digital display, is presented in [12].

1.2 Contribution and paper structure

In our system, the flow meter is connected to the ATMIGA 2560 arduino to open and close a valve passing water to the customer tank. The flow meter utilizes the acoustic signals to measure the speed of passing water and sends a corresponding signal to the arduino indicating that speed. The arduino computes the quantity of water passed through the valve. When the needed quantity of water is reached, the arduino sends a signal to the valve to close it. This is explained in details in section (3).

The paper is organized as follows: Section (1) is an introduction. It introduces the idea and objectives of the paper and it also comprises some related work that has been done by researchers in this field. Section (2) gives in details the proposed system design. Section (3) presents the system evaluation, simulation results, and discussion. Some conclusions and future work points are given in section (4). A list of references and a list of abbreviations are given at the end of the paper.

2. The Proposed System

The block diagram of the proposed system is shown in figure (1). In the following, the different blocks, of this diagram, are described.

2.1 The operator

The operator may be a normal employee. In the future automatic operations may be done using artificial intelligence. In this block, the operator may perform one of two processes:

a) To start a session by:

1) Pressing the start button which sends a staring signal “Start” to the controller.

2) Inputting the value of the needed quantity of water to be delivered to the customer (Wn).

b) To stop or interrupt the session in case of any abnormal situation

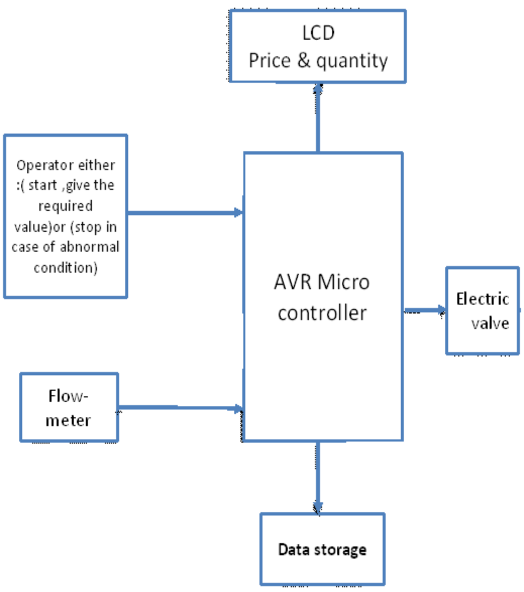

Figure 1: Block diagram of the simple proposed system which can perform the SCADA tasks.

2.2 The Ultrasonic Flow Meter

The term "ultrasonic"’is used to describe pressure waves at frequencies higher than the human ears can detect. The velocity of the sound waves in the fluid is the same as the velocity of sound in the fluid. If an ultrasonic beam is transmitted across a pipeline at an angle to the flow direction, the time taken for the pulse to reach the receiver is a function of the flow velocity of the fluid, as well as the velocity of sound in the fluid. Thus, this type of flow meter operates on the principle of transit time differences. An acoustic signal (ultrasonic) is transmitted from one sensor to another. This can be either in the direction of flow (downstream) or against the direction of flow (upstream). The time (transit) that the signal requires to arrive at the receiver is then measured. According to physical principles, the signal sent against the direction of flow requires longer to return than the signal in the direction of flow. Figure (2) explains this process [11-12].

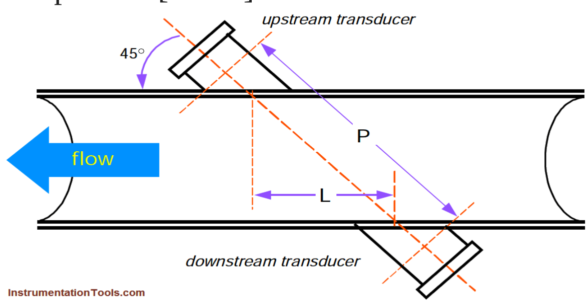

Figure 2: The transit process of acoustic signals through a fluid pipeline. The signals travel faster in the flow direction than in the reverse direction.

The difference in the transit time (Δt) is directly proportional to the velocity of flow (S): i.e. $S \approx \Delta t$, then, we can write:

$$S = k\,\Delta t \qquad (1)$$

where k is a constant

Flow rate (Q) is thus:

$Q = S \, . A = A \, k \, \Delta t$ (2)
where,
S = flow velocity
Δt = transit time difference between the signal in the direction of flow and against the direction of flow
Q = volumetric flow rate
A = pipeline cross-sectional area

From another side, the sent signal from the flow sensor to the controller has a voltage that is proportional to the flow rate. This means that:

Flow rate (Q) α Voltage (V), then, we can write:

$Q = a \, . V$ (3)

where (a) is a constant, by experiment, it is found to be 2.5 Liter/(sec . volt). Hence,

$Q = 2.5 \, V \quad or \quad V = 0.4 \, Q$ (4)

Transmitter and receiver roles are switched by electronics. Ultrasonic pulses, traveling in the direction of the flow, travel the path between transducers in a shorter period of time than pulses traveling against the flow. A mapping process is carried out to map the voltage values into the corresponding water quantities passing through the pipeline. This mapping is a software operation that uses the map function is used to map a number from one range to another. That is, a value of **fromLow** would get mapped to **toLow**, a value of **fromHigh** to **toHigh**, values in-between to values in-between, etc. The syntax of the used function takes the form:

map(value, fromLow, fromHigh, toLow, toHigh)
where:
value: the number to map.
fromLow: the lower bound of the value's current range.
fromHigh: the upper bound of the value's current range.
toLow: the lower bound of the value's target range.
toHigh: the upper bound of the value's target range.

The function does not constrain values within the range, because out-of-range values are sometimes intended and useful. The constrain() function may be used either before or after this function, if limits to the ranges are desired. Note that the "lower bounds" of either range may be larger or smaller than the "upper bounds" so the map() function may be used to reverse a range of numbers, for example

y = map(x, 1, 50, 50, 1);

The function also handles negative numbers well, so that this example

y = map(x, 1, 50, 50, -100);

is also valid and works well.

The map() function uses integer math so will not generate fractions, when the math might indicate that it should do so. Fractional remainders are truncated, and are not rounded or averaged.

2.3 The microcontroller

The controller is the main part of the system. It allows us to measure the flow rate and check the volume of the water passing through a pipe. Thus, we can control the water quantity. The type of arduino is Atmega2560. It performs all the computations and generates all the control signals based on the operating conditions. It uses one analog pin to detect the analog signal received from flow meter. The signal current range is 4-20 mili Ampere. The signal is converted to mili-volt before entered to a resistor of 250 ohm. Thus, the signal voltage is then 1000-5000 mili volts.

The flow sensor sends a corresponding signal to the microcontroller representing the water flow rate passing through the meter. The microcontroller sums up these values and maps the result into the corresponding water quantity. The detailed connection of the flow meter to the microcontroller will be given in section (3.7). However, it performs the following tasks:

a) Receives the "Start" signal from the operator
b) Receives the value Wn from the operator
c) Once it receives the "Start" signal, it sends a signal to a relay that opens the valve of the water pump such that water is pumped to the customer tank. There is a flow-meter that counts the quantity of water pumped to the customer (Wp).
d) Receives a signal from the flow-meter that indicates the quantity of water pumped to the customer (Wp)
e) Computes the difference between the needed quantity and the pumped quantity of water (Wd) where:

$$W_d = W_n - W_p \quad (5)$$

f) When Wd = 0, it sends a signal "Stop" to a relay that closes the valve of the water pump such that pumping water stops.
g) During the pumping operation, it computes the price of pumped water.
h) The pumped quantity of water and the corresponding price are monitored on special LCDs and stored on a storage medium.
Figure (3) describes the connection of the flow meter to the arduino.

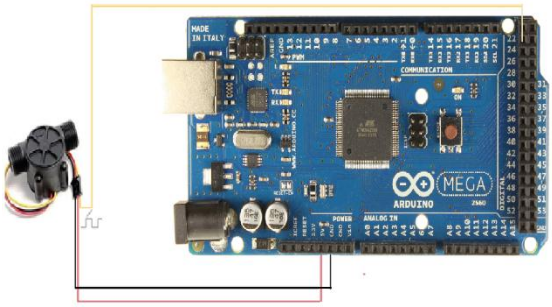

Figure 3: A simple connection of the flow meter to the arduino using only three wires.

2.4 The electro hydraulic part:

This part is responsible for pumping the water to the customer tank. It receives electric signals that actuate relays which open or close the valve of the water pump. These signals are generated by the controller. The "Start" signal is generated once the operator press the "Start" button and the "Stop" signal is generated once the value Wd is zero. Also, under abnormal conditions of operation, a "Stop" (or interrupt) signal may be generated when the operator presses a "Stop" button. Once the "Start" signal is received by the valve relay it opens to allow the water to flow in the pumping tube from the water source to the destination (the customer tank). When a "Stop" signal is received by the relay, this valve closes and stops the pumping operation.

2.5 The system algorithm:

Here you give the whole algorithm of the system as follows:

Start the system
If there is any abnormal condition then interrupt or "Stop" the session.
Else
Press the start button to start a session
Enter Wn, where Wn is the needed quantity of water to be pumped to the customer.
Generate the "Start" signal if quantity > 0 & "start"=1 then connect relay to "high level"(open the valve)
Else
Connect to low level (close the valve)
At intervals of 100 liters send the value to the controller
Compute Wd
If Wd = 0 actuate the valve close relay and close the valve.
Stop
End
Figure (4) gives the flow chart of this algorithm.

2.6. Practical Implementation

The proposed system has been implemented and used in Matrouh Water Company. Figure (5) explains the circuit diagram of the proposed system and Figure (6) gives the layout of the practical implementation of the proposed system.

Figure (7) gives the shapes and some specifications of the elements used in the practical implementation.

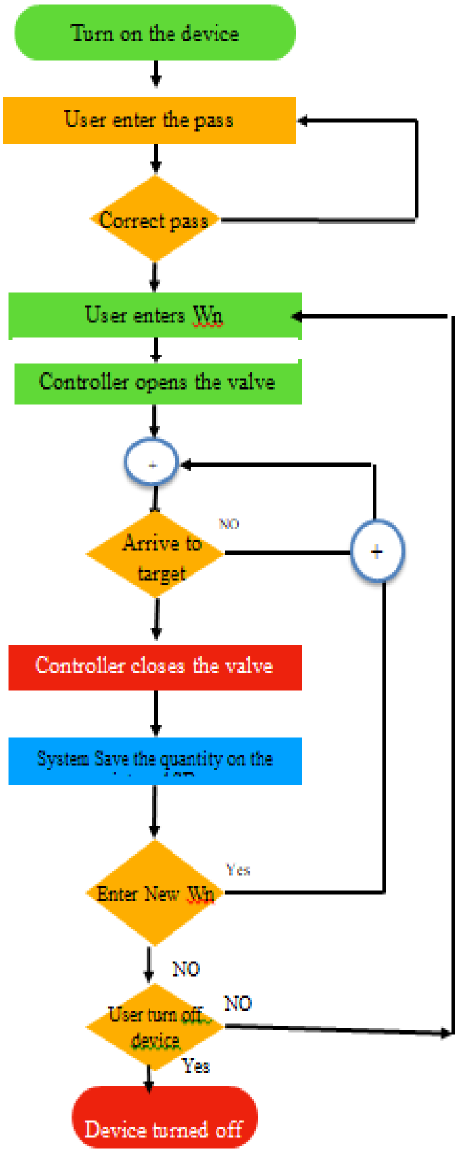

Figure 4: The flow chart of the proposed system

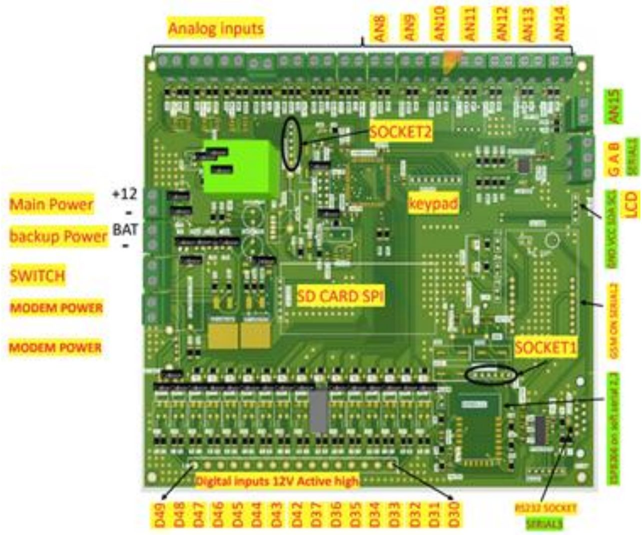

Figure 5: Circuit diagram of the proposed system

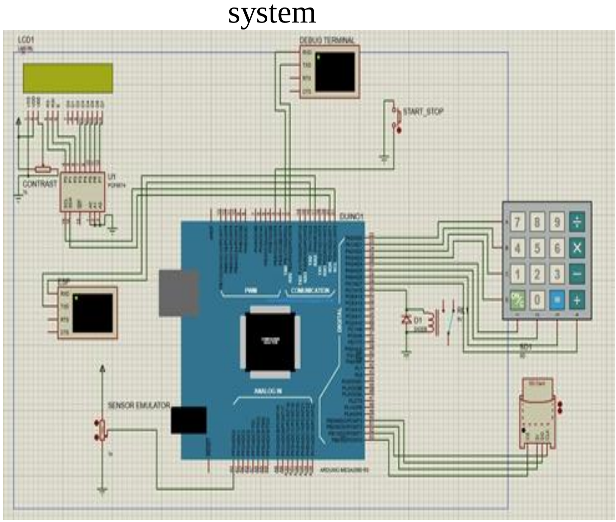

Figure 6: Practical implementation of the proposed system

Microcontroller atmega 2560

Keypad Standard Matrix Key Pad 4×4 Flat (Calculator Shape)

Internal memory: Micro SD Card Module For

Relay Relay Module 5Vdc – 1 Relay For Arduino

Arduino or MCU

LCD LMB204BFC (Character LCD 4×20) Blue , Original

Ultrasonic flow meter euromag 100mm

& Microcontrollers

Electrical valve bater flay valve

Figure 7: Elements of the practical implementation of the proposed system

3. Results and Discussions

The proposed system makes it possible to completely control the amount of water discharged to citizens with the possibility of real-time recording of data, and the process of control and operation does not need special specifications from employees, which helps to control the water system economically, whether in the construction or operation phases. For a quantity of water 15000 liters (i.e. 15 m^3), table (1) gives the flow rates of water, the corresponding voltage values, the time of the flow, and the corresponding total quantity of water passed through the pipeline. Figure (8) gives the timing diagram of the total quantity of water with respect to time. The total waste of time in the station is reduced to a very low value. This confirms that the system fulfills a high accuracy. Comparing this system to other SCADA systems, it can be seen that the system is very cheap compared with SCADA systems and also it does not need any training or experience for the employees to run and use it. The system is applied in the Matrouh water station.

Table 1: Quantity and signal with time

Flow rate (Q) (M^3/sec)	Signal voltage (V)	Time (seconds)	Total Quantity (m^3)
4125	1650	t1	4125
4125	1650	t2	8250
4125	1650	t3	12375
2625	1050	t4	15000

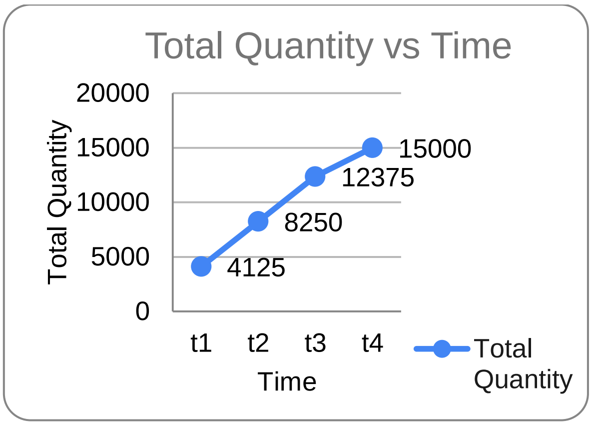

Figure 8: Quantity with time

4. Conclusions

In this paper, a simple SCADA system for water companies is proposed. This system can be utilized to distribute water from water stations to the citizen houses, especially in the remote areas where the water networks are not available. The proposed system can replace the complicated highly costing SCADA systems. The system depends on using the fluid ultrasonic flow meters connected to arduino Atmiga2560 microcontroller. The microcontroller receives two signals which start/stop the flow process by opening/closing the flow valve. The first signal which starts the flow process by opening the valve is received when the operator switches the system on and enters the required quantity of water and then presses enter. Once the microcontroller receives this start signal, it sends a signal to the valve to open. Based on the flow rate of the flow meter, a corresponding signal is sent from the flow meter to the controller. The microcontroller maps the voltage value of this signal to a water quantity that corresponds to the flow rate. The value of passing water is computed with time, till the required quantity of water is reached. At the same time of supplying the water through the pipeline, the price is computed and sent to an LCD display as well as a storage medium. Once the required water quantity is reached, the controller sends a signal to the valve to close and then the flow stops. This system is applied in Matrouh water station. It has proved the conditions of easy to use (any employee, with no experience, can run it) as well as the accurate results (water waste has been reduced by 44000 m^3 monthly).

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Appendix 1: A List of Abbreviations

Abbreviation	Terminology
AVR ATmiga2560	automatic voltage regulator (Arduino Mega)

LCD	Laser Crystal Display
Arduino	An open-source electronics platform or board and the software used to program it. he name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014 (Ref: https://en.wikipedia.org/wiki/Arduino)
SCADA	Supervisory Control and Data Acquisition
IoT	Internet of things
HMI	Human Computer Interface
SMS	Short message service