Research Article Impact Factor: 0.621 ISSN: 2319-507X
Sonali Lagu, IJPRET, 2014; Volume 2 (9): 25-32 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

AUTOMATION OF WATER TREATMENT PLANT USING RASPBERRY PI

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Accepted Date: 27/02/2014 ; Published Date: 01/05/2014

Abstract: Automation of water treatment plant has already been developed and widely used in many countries. But most of them use programmable logic controllers-PLCs. This paper focuses on an innovative and intelligent control and monitoring system for Water Treatment Plant by using “Raspberry Pi” as an effective alternative to PLCs for the automation of small water treatment plants. Raspberry Pi is a minicomputer which has an ability to control the system comes with advantages like low cost and compact size.

Keywords: Raspberry Pi, Automation, water treatment plant, process control

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Access Online On:

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How to Cite This Article:

Sonali Lagu, IJPRET, 2014; Volume 2 (9): 25-32

PAPER-QR CODE

INTRODUCTION

Water is one of the most important natural resources and is of vital importance for all living things on the earth.

Up to 60% of human body is water. Therefore quality of water we drink is very important. The drinking water should be clean, pure and free of microorganisms and it should be treated and disinfected before consuming it.

Water treatment plants treat the raw water from river, lake, reservoirs or other underground sources and provide safe and reliable drinking water to mankind. Automation is a key to water treatment plant management since it has various tangible and intangible benefits. Tangible benefits include reduction of labour cost, reduction in travel time to secluded locations, operational improvements, etc while the intangible benefits include uniformity, better data collection, better monitoring and security, etc.

Conventionally, Programmable Logic Controllers (PLCs) have been used for automation of water treatment plants. This paper focuses on an innovative and intelligent control and monitoring system for Water Treatment Plant by using "Raspberry Pi" as an effective alternative to PLCs for the automation of small water treatment plants. Raspberry Pi is a minicomputer which has an ability to control the system comes with advantages like low cost and compact size.

Purification of water consists of various operations like coagulation, flocculation, sedimentation, filtration and disinfection. Automation of these operations involves monitoring and control of various sensors, actuators and motors. These sensors, actuators and motors can be skillfully controlled using Raspberry Pi. Graphical representation of entire water treatment process, which can be displayed on the LCD connected to Raspberry Pi. Graphical user interface can be designed with the help of programming languages like Python and Tkinter.

- **Overview of water treatment plant**

Raw water from river, lake, reservoir or underground water sources is supplied to water treatment plant for the treatment process. Most commonly used processes include coagulation, flocculation, sedimentation, filtration and disinfection.

In the first stage of water treatment plant, the raw water flows through an aeration fountain (as shown in Figure 1). In this stage, oxygen gets dissolved in the water and the ultra violet rays from the sunlight eradicate the microorganisms present in the water.

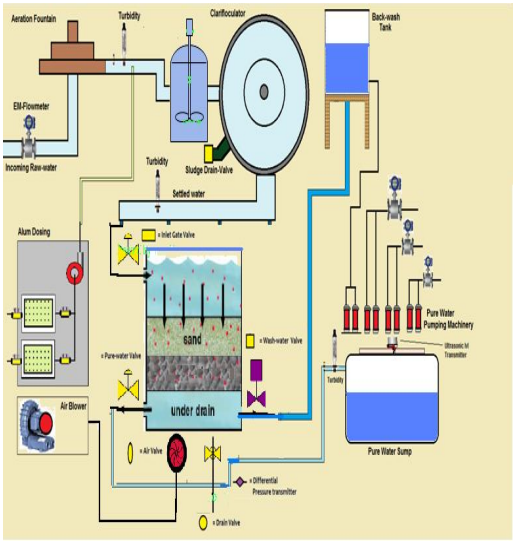

Figure 1: Graphical representation of automation of water treatment plant

In the second stage, water undergoes coagulation process. In this process, coagulant such as aluminum sulfate (or alum) is added to water using alum dosing pump (as shown in Figure 1). These coagulant form sticky particles called as 'microfloc' which attract dirt particles. This water with coagulant is mixed gently for longer time with help of flash mixer (as shown in Figure 1). Chemical reaction due to gentle mixing of water and coagulant cause microfloc, dirt, bacteria to form larger particles called as 'floc'. This process is referred to as 'flocculation'. [4]

In the third stage, water exiting the flash mixer enters clariflocculator basin. It is a large tank with low water velocities, allowing floc to settle to the bottom. As particles settle to the bottom of a sedimentation basin, a layer of sludge is formed on the floor of the tank. This layer of sludge must be removed. The amount of sludge that is generated is significant, often 3 to 5 percent of the total volume of water that is treated. The sedimentation tank may be equipped with mechanical cleaning devices that continually clean the bottom of the tank or the tank can be periodically taken out of service and cleaned manually. Water flowing out of clariflocculator is often termed as settled water. [5]

After separating most floc, the settled water is filtered as the fourth and final step to remove remaining suspended particles and unsettled floc. Settled water moves vertically through the filter bed consisting of layers of sand, gravel and activated carbon or anthracite coal (as shown in Figure 1). This step removes turbidity and organic compounds, which contribute to taste and odour.

To clean the filter bed, water is passed quickly upward through the filter, opposite the normal direction (called back flushing or backwashing) to remove embedded particles. Prior to this step, compressed air may be blown up through the bottom of the filter to break up the compacted filter media to aid the backwashing process; this is known as air scouring. This contaminated water can be disposed of, along with the sludge from the sedimentation basin.

Filter bed with single cell has one inlet valve (settled water comes in), one outlet valve for pure water, drain valve, air blower and backwash water valve. Backwashing process is often triggered by differential pressure sensor installed in filter bed which senses the difference between the pressure of settle water and pure water.

Chlorine is added to water as disinfectant. Turbidity of raw water, settled water and pure water is measured using turbidity sensors to maintain quality of water.

Pure water from the filter bed is ready for consumption and is stored in pure water sump.

- **Role of Raspberry Pi in the automation of water treatment plant**

Heart of the system is Raspberry Pi minicomputer. Raspberry Pi model B has dedicated general purpose input outputs pins. These GPIO pins can be accessed for controlling hardware such as LEDs, motors, and relays, which are all examples of outputs. As for inputs, raspberry pi can read the status of buttons, switches, or it can read sensors like temperature, light, motion, or proximity sensors. Some GPIO pins have alternate function such as UART, SPI, I2C etc. [1]

Automation of water treatment plant involves different types of sensors, actuators and motors which can be interfaced with Raspberry Pi GPIO pins. Display of 24 inch TV can be connected to composite PAL of Raspberry Pi. [2]

Ultrasonic flow meter measures the rate of flow of water to the plant. Ultrasonic flow meter has 4-20 mA output which corresponds to water flowing with unit liters/sec. Raspberry Pi cannot read analog input since there are only digital inputs present on the board. So, analog output of flow meter (4-20ma) is converted into 0-5 volts. We can use analog to digital convertor MCP3008 which converts 0-5 volts into 10 bit digital output. MCP3008 is 10 bit 8 channels ADC which can be interfaced with Raspberry Pi using SPI protocol.

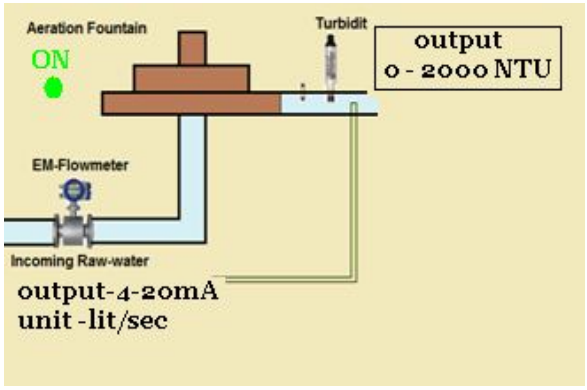

Figure 2: GUI Aeration Fountain, Flow meter, Turbidity

Turbidity of incoming water, settled water and pure water is measured using turbidity sensors having 4-20 mA output. Again this analog output is converted in 0-5volts and connected to one of channel of ADC MCP3008. Raspberry pi reads the output from flow meter and turbidity sensor, and then displays it on 24 inch TV screen connected to it. User can monitor real time data of flow meter, turbidity and status of aeration fountain on the simple GUI designed using Python and Tkinter as shown in Figure 2.Once the flow of water has been detected, Raspberry Pi switches ON one of the digital output to turn ON the flash mixer. Also alum dosing pump is switched ON by Raspberry Pi to commence the process of coagulation and flocculation as shown in Figure 3.

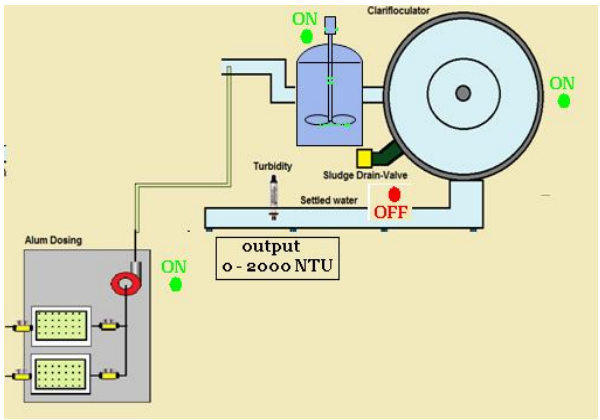

Figure 3: GUI Status of Alum dosing pump, Flash mixer, Clarifloculator

Two digital output pins of Raspberry Pi are used to control clarifloculator. Once the clarifloculator is switched ON by Raspberry pi GPIO, settled water flows towards filter bed. [2]

The inlet valve needs to be opened for filtration process. Actuators are required to control the operation of valves. Actuator consists of two parts, seating of actuator and drive of actuator.

Seating of actuator consists of two limit switches to detect the position of valve i.e. open or close. Drive of actuator consists of two motors, forward rotation of motor and reverse rotation of motor which contributes to 2 digital outputs. It requires 2 digital inputs and 2 digital outputs of Raspberry pi to control the operation of actuator which in turns control inlet valve. Similarly outlet valve for pure water is controlled by Raspberry Pi. This can be seen in Figure 4.

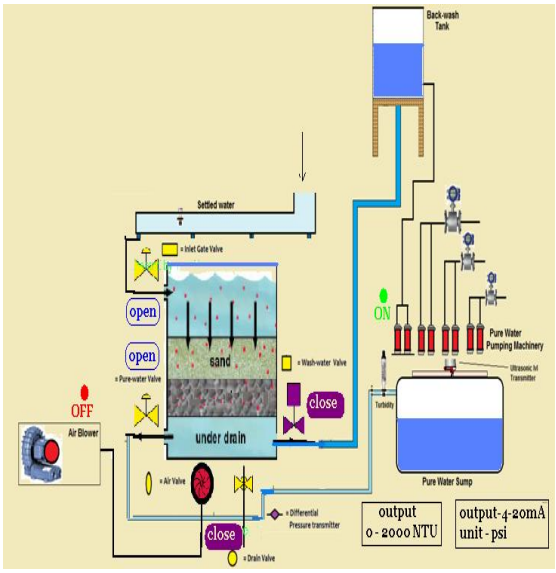

Figure 4: GUI Filter bed normal operation

Differential pressure sensor is installed in filter bed which has 4-20 mA output. The output of differential pressure sensor is converted to 0-5volts and connected to one of the channel of ADC mcp3008. Raspberry Pi reads the output of differential pressure sensor. When the pressure of settled water is 1.8 times more than pressure of pure water, Raspberry Pi isolates filter bed from rest of the plant by closing inlet and outlet valve and initiates backwash process. In backwash process, Raspberry Pi switches on the air blower which is connected to one of its GPIO .drain valve and backwash water valve is opened by Raspberry Pi. Once the filter bed is washed and cleaned, Raspberry Pi switches off the air blower, closes the drain valve and backwash water valve, and opens the inlet and outlet valve. Level sensor is installed in pure water sump. Its output is 4-20 mA which is connected to Raspberry Pi through ADC mcp3008. Pumps are operated by Raspberry Pi depending on the water level in sump. This can be seen in Figure 5.

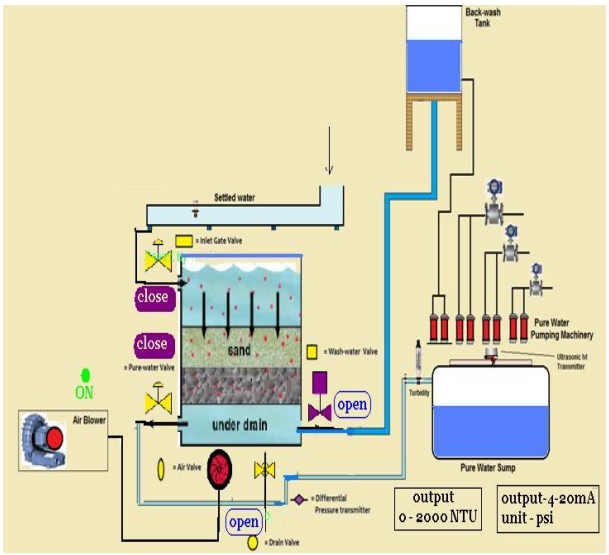

Figure 5: GUI Filter bed backwash operation

Total number of digital inputs is 10 and total number of digital outputs is 16. Number of GPIO pins of Raspberry Pi is limited. It can be extended using IO expender IC e.g. MCP23008 which has I2C interface as shown in figure 6.

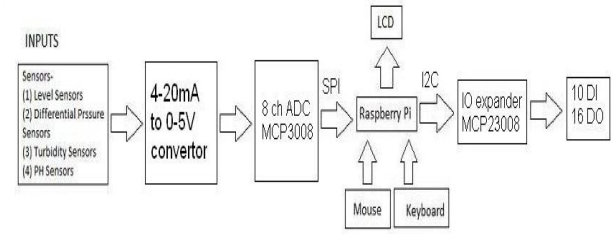

Figure 6: block diagram of raspberry pi system

- **Hardware prototype: raspberry pi**

The Raspberry Pi is a small computer about the size of a credit card and costs approximately £25.Raspberry Pi Model B has 512Mb RAM, 2 USB ports and an Ethernet port [1]. It has a Broadcom BCM2835 system on a chip which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU, and an SD card. It has a fast 3D core accessed using the supplied OpenGL ES2.0 and OpenVG libraries. The chip specifically provides HDMI, TV and there is no VGA support. The foundation provides Debian and Arch Linux RM distributions and also Python as the main programming language, with the support for BBC BASIC, C and perl. [2]

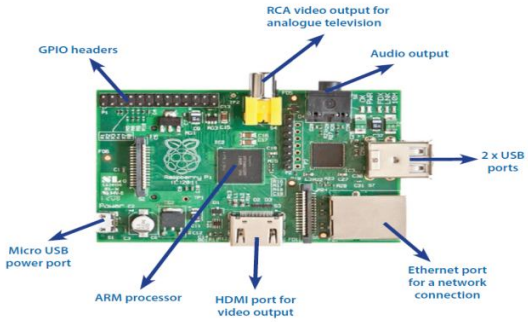

Figure 7: Raspberry Pi Model B

- **Further enhancements**
- Connecting usb memory stick to raspberry pi for data logging
- Ethernet connectivity
- Wi-Fi connectivity
- Uploading data on website.

CONCLUSION

Raspberry pi based automation is a novel and advance technology. Use of raspberry pi dramatically reduces the price of the system. But still there are some drawbacks like it has very limited memory and limited number of GPIO which makes it difficult to store data and process it. If these obstacles are overcome then it will become a great standalone embedded platform for different solutions.

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