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Water Quality Monitoring System Using Zig-Bee and Solar Power Supply

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ABSTRACT: This work presents a water quality monitoring system using wireless sensor network (WSN) technology and powered by solar panel.. To monitor water quality over different sites as a real-time application, an excellent system architecture constituted by distributed sensor nodes and a base station is suggested. The nodes and base station are connected using WSN technology like Zigbee. Design and implementation of a prototype model using one node powered by solar cell and WSN technology is the challenging work. Data collected by various sensors at the node side such as pH, turbidity , conductivity, salinity and temperature is sent via WSN to the base station. Data collected from the remote site can be displayed in visual format as well as it can be analyzed using different simulation tools at base station. This novel system has advantages such as no carbon emission, low power consumption, more flexible to deploy at remote site and so on.

KEYWORDS: WSN; conductivity sensor; salinity pH sensor; Turbidity; Zigbee, water quality monitoring; WSN; solar power; real-*time*

I. INTRODUCTION

A Wireless sensor network (WSN) consists of spatially distributed autonomous sensor to monitor water parameters such as pH, Salinity, Turbidity, conductivity, temperature. The more modern networks are bi-directional. The WSN is built of five nodes, each node is connected to one sensor. There are five sensors, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. There are many opportunities for using wireless sensor networks within the water/wastewater industries. Data transmission can be monitored using industrial wireless I/O devices and board. Water pollution is the contamination of water bodies. Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution affects plants and organisms living in these bodies of water. In almost all cases the effect is damaging not only to individual species and populations, but also to the natural communities. Water covers over 70% of the earth's surface and is a very important resource for people and the environment. Water pollution affects drinking water, rivers, lakes and oceans all over the world. This consequently harms human health and the natural environment. Here you can find out more about water pollution and what you can do to prevent it.

The water quality monitoring system proposed is made up by a base station and several sensor nodes. The sensor nodes are located in different sites where we need to monitor water quality. The base station contains a wireless receiver and a PC, where users can receive data from sensor nodes and analyze it. The base station can still connect to Ethernet so that users can login and get data faraway. The nodes and base station are connected via WSN technology. To make the system more flexible to deploy, solar panel is used in this system to supply power to the sensor node, together with an accumulator to recharge when solar power is not enough, such as night.

II. SYSTEM ARCHITECTURE

Water is essential resource of life for each living organism on the earth. Oxygen level in water plays important role in examining quality of water. Water quality plays important role in the health issues of human, plant and living organisms on the earth. Generally, main sources of water are rain, rivers and lakes. Rain water running over the lands contains many useful as well as harmful contents, may be soluble or insoluble. Acidity of water is decided by the salt and

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particles in soil. Traditional measure of water quality is transparency of water that means insoluble particles mixed in water degrades usefulness of water for particular application. The main aim is to measure the Ph, Salinity, Conductivity, Temperature and Turbidity of drinking water as well as water that may be used for agriculture and industrial processes. The remote access of water quality measurement parameters using wireless communication facilitates quality control, record keeping and analysis using simulation software at base station. Oxygen level, pH and turbidity level are the parameters that are analyzed and control to improve water quality.

Following are the objectives of idea implementation. Measurement of Ph, Salinity, Conductivity, Temperature and Turbidity of water using available sensors at remote place.
To avail local power supply to sensor nodes using solar energy.
To collect data from various sensor nodes and send it to base station by wireless channel.
To control data communication between source and sink nodes.(Synchronization using time division)
To simulate and analyze quality parameters for quality control. (Graphical and numerical record using VB & MATLAB)
To publish the corresponding record over web for public information and further assessment of water resource.
The detailed block diagram of water quality monitoring system is shown in Figure 1.

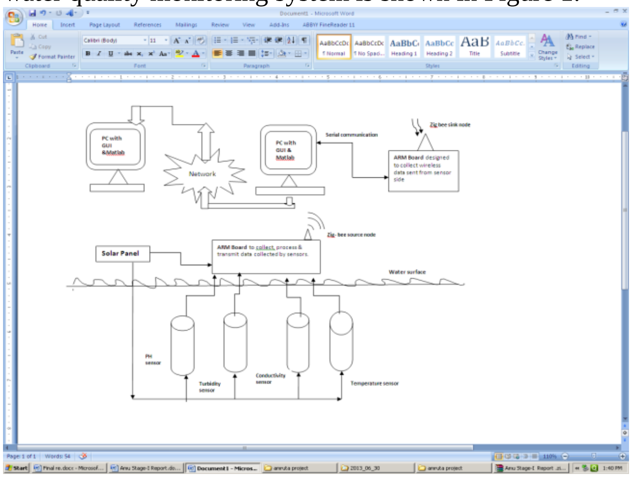

Fig.1 Block diagram of proposed Underwater Sensor Network.

III. HARDWARE DESIGN

In this part we are going to discuss the detailed design of pH sensor interfacing, oxygen sensor interfacing, turbidity sensor interfacing and solar power module.

pH Sensor Interfacing

The high accuracy pH probe IH20 is used as a pH sensor which has output voltage from -412mV to 412mV. The theoretical output of the IH20 pH probe is approximately 59.16 mV/pH at 25°C, i.e. for acid output voltage is positive, for neutral it is null and for bases it becomes negative with 59mV per unit pH starting from null. This output voltage is affected by environmental temperature thus it is required to compensate the temperature factor. The necessary arrangement is done to compensate the temperature effect as shown in figure 2. Output of IH20 sensor is converted into 0~2.5V range which is further given to ARM processor for processing.

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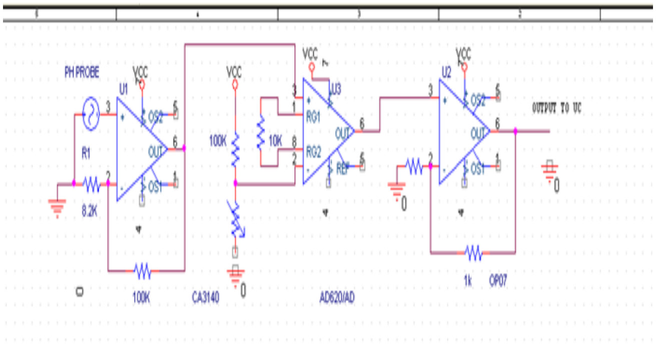

Fig.2 Circuit diagram of IH20 sensor interfacing.

Turbidity level sensor interfacing

Turbidity is the phenomena where by a specific portion of a light beam passing through a liquid medium is deflected from undissolved particles. Turbidity is caused by suspended particles in water. Suspended particles block a lot of incident light and scattered light. It also diffuses the incident light. Therefore, photo electricity sensor is used to detect turbidity. The most widely used measurement unit for turbidity is the FTU (Formazin Turbidity Unit). ISO refers to its units as FNU (Formazin Nephelometric Units).

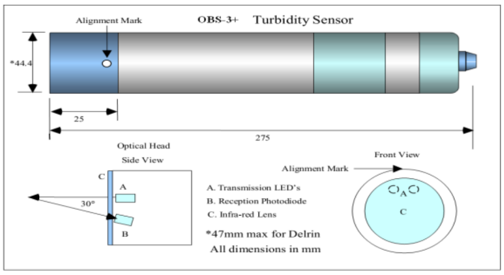

Fig.3 working principle of Turbidity sensor

Turbidity sensor is to measure the clarity of water, the output voltage range represents turbidity value ranging from 0 to 4000NTU (Nephelometric turbidity unit) .Output of circuit is 0~5V which is transferred to 0~3v compatible to ARM controller. The Turbidity level sensor interface circuit is shown on figure 4.

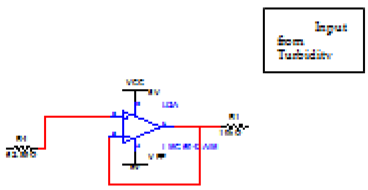

Fig.4 Circuit diagram of Turbidity level sensor interfacing.

Temperature sensor interfacing

The RTD PT –100 is connected in bridge circuit as a temperature sensor. The signal conditioning circuitry is as shown in figure 5.

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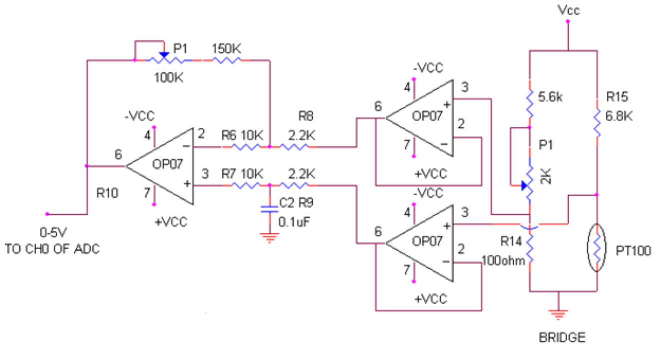

Fig.5 Temperature sensing circuit

Depending on the application of temperature the resistance of PT-100 changes proportionally which gives further changes in the output voltage of the bridge circuit at 0˚C the bridge will be in balanced condition but as the temperature of the PT 100 changes due to application of some temperature input, then the bridge circuit becomes unbalanced. This unbalance results in small diff voltage across the bridge output. Maximum diff voltage will be from 20 to 40mv. This small voltage is fed to the differential amplifier for the amplification purpose. The gain may be from 150 to 300 to adjust full scale o/p. The Output of differential amplifier is then further fed to the ADC of ARM7.

Conductivity and salinity measurment

Conductivity sensors are generally divided into two types: two electrodes or multiple electrodes. Conductivity of two electrodes is commonly used interiorly. Generally, two conductivity electrodes in laboratory can be made by using two platinized platinum to sinter on two parallel glass, or inner wall of the round glass tube. Changing the size of platinum pieces and adjusting the distance between them can make different constant value of two conductivity electrodes.
VATS Conductivity cell is an insertion type sensor, in a robust and compact housing. VATS Conductivity sensor are designed to provide versatile installation and accurate sensing across a very broad dynamic range. Coupled with VATS meters in a range with ±2% of reading accuracy is achieved without the need for troublesome sensor platinization. Standard wiring allows connection without costly "patch cord".
Salinity of water is calculated in terms of total dissolved solids in water. It is calculated from conductivity of water. It is measured as:

[(TDS)ppm = Conductivity µS/cm x 0.67].

Zigbee module interfacing

A wireless technology like Zigbee works on standard IEEE 802.15.4 protocol & operates on unlicensed bands worldwide at the frequencies 2.400-2.484GHz, 902-928MHz and 868.0-868.6MHz. Low cost, low power (3.3V), and up to 65000 nodes with an AES encryption standard for communication are the main advantages of Zigbee. Figure 5 shows interfacing of Zigbee with controller board. [2]

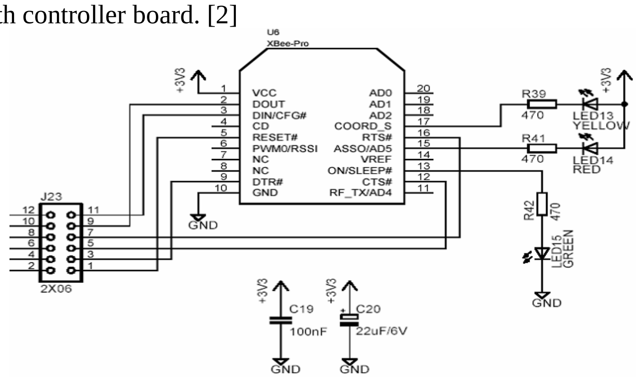

Fig.5 Interfacing Of Zigbee with ARM Board.

Advantages of using Zig-bee in the system:
It provides very effective point to point and line of sight communication.

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By using proper antennas range of communication can be extended upto 5km in this system.
Unlike GSM or Wi-fi No continuous radiation of power is required at remote monitoring place.
More secured, easy and cost effective solution for dedicated applications.

Solar panel interfacing

In a practical water quality monitoring system, where sensor nodes are distributed in remote sites, power supply has become an extremely important issue, sometimes even the bottleneck of the system. Using wires to connect nodes to power lines nearby is not practical, because the nodes usually distribute in remote places, and the total expense in connecting all these nodes is unbearable. Another method is to use battery only. The advantages are obvious, but batteries have limited lifespan and cannot stand for a long time. Replacing depleted batteries regularly is inconvenient. To avoid unnecessary work and make the system more flexible to deploy, solar panel is to use in this system to supply power for the sensor node, together with the battery to recharge when solar power is not enough, such as night. [8]
The output voltage and power of the solar panel used is 13.5V, 1.5W. Since the sunlight changes day and night, a battery with 12V output is needed to store and maintain the output voltage of the solar power module. When the sunlight is strong and solar panel outputs higher than 12V, the regulator turns on, thus solar panel powers remaining blocks and battery is in charging mode. When the sunlight become poor, the regulator turns off & the whole sensor node is powered by 12V battery. Solar charging controller 12 V/DC, 6 A [M149] is used as a regulator to convert 13.5V into regulated 12V DC. Figure 6 below shows the detailed diagram of solar power module. [8]

Solar Panel
(13.5V, 1.5W)
Regulator (M149)
12V DC

+
-
12V rechargeable Battery

Fig.6 Solar Panel Power Regulation & Storage.

ARM- Base control

All sensors and Zigbee modules are connected to the ARM controller board designed for special compact space application using surface mount technique. RISC processor architecture of LPC2138 (ARM7) has many advantages in water quality monitoring system such as low power consumption, low cost, optimum baud rate and maximum operating frequency (12MHz). On chip ADC is fascinating feature of ARM processor that facilitates direct interfacing of sensors to ARM board and reduces space. 3.3V power consumption of ARM controller is much lesser than available power from solar module.[4]

IV. SOFTWARE DESIGN

Software design approach for water monitoring system is based on three parts, first is ARM programming, GUI design in VB and MATLAB simulation of results obtained from base module. Detailed flowchart for the working of whole system as well as software design is shown in figure 7.

N
Y
VB displays & converts data into format (.txt).
Day wise Graphical analysis is shown in MATLAB
Control action can be taken by observing comparative graphs
Stop
µc will show the data on LCD & send it to Zigbee
LCD display the data
Zigbee module will transmit the data
Data received by Zigbee at Base station
Received data is given to the ARM

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Start
Collect data from sensor
Data is being sent to ARM
VB reads HyperTerminal
Data at base station is shown on LCD &send it to HyperTerminal
Time lap complete?
.txt files are read by MATLAB

Fig.7 General Workflow of water quality monitoring system

ARM programming is done in Keil uVision4 IDE software. GUI on PC to display collected data is designed using VB 6.0. For comparative day wise graphical analysis of data collected from sensor nodes is done in MATLAB 7.1.

V. RESULTS

The graphical user interface using VB 6.0 is shown in figure 8. Data collected by sensors is sent to the base station via WSN channel. The base station is usually a PC with Graphic User Interface (GUI) for users to analyze water quality data or alarm automatically when water quality detected is below preset standards.

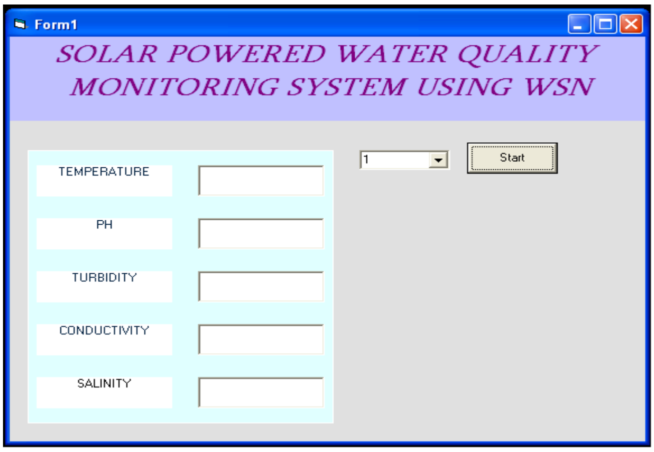

Fig.8 Snapshot of GUI of results displayed on PC.

Graphical results in MATLAB are the hourly representation of data collected day wise which is not shown here. The comparisons between results are used to monitor the seasonal water quality and environmental accidents under water. Following figure shows waveforms in Matlab with respect to time.

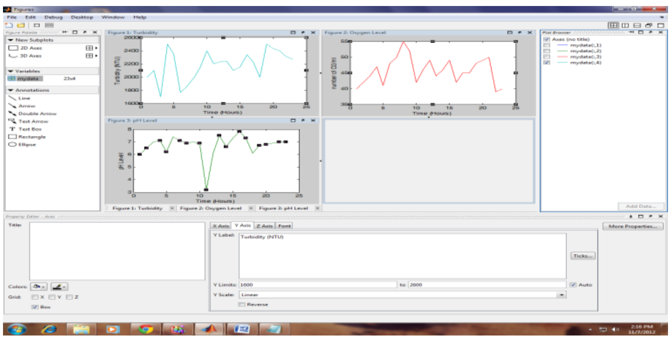

Fig.9 Snapshot of GUI of results analysis displayed on MATLAB.

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VI. APPLICATIONS & FUTURE SCOPE

This system checks quality of water at the places where generally it is inconvenient to take frequent tests manually.
The higher turbidity and imbalance of pH in water supply used for drinking, agriculture and even for industry use is a serious issue. At such places the quality control can be done by monitoring the water and taking necessary action for quality improvement. The running water over particular land gets mixed with salt and other materials which changes the pH of water and is turbidity. The analysis of the material contents in the soil in that particular region can be monitored easily at the base station using the same system. In order to monitor water quality in different sites, future works can be focused on establishing a system with more sensor nodes and more base stations. Connections between nodes and base station are via WSN, while connections among different base stations are via Ethernet. The Ethernet can also be connected to Internet so that users can login to the system and get real time water quality data faraway. Another interesting field lies on the optimization of power consumption and data throughput of the WSN. The wireless data acquisition from remote places and database storage is the supporting structure of the system which can be used for further research studies like soil content analysis using different simulators. The simulation can be used for water pollution control in varying conditions. Also it can be used to guess abnormal moments in sea stomach by measuring the turbidity at sea shore.

VII. CONCLUSION

Monitoring the quality of water & collecting comprehensive data, achieves sequential follow up of water pollution status in remote region. This system not only provides comprehensive evaluation of water environment but also can quickly discover urgent water pollution accidents or natural disasters, transferring the abnormal water quality information to monitoring center by quicker communication network and provides graphical references for the decision-making department to comprehend the status of the disaster to establish the prevention and cure policy.

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