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A REVIEW ON WATER LEVEL MEASUREMENT AND CONTROL

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Abstract

A review on different methods used to measure the level of water in a reservoir and its control. Water is an extremely important resource for every living organism on the planet and its wastage should be prevented. Water level measurement in overhead/underground tanks and its control is very crucial. A number of methods are there to measure the level of water in a reservoir and most of these methods have their advantages and disadvantages. The different water storage methods have their unique challenges in water level measurement and it control. Various types of sensors are used to make the measurements and an appropriate communication technology is used. Here a survey of the different method used for the measurement and control are discussed. Zigbee based measurement and control system was found to be the most efficient.

Keywords: Water Level, Sensors, Ultrasonic, ZigBee, Control

I. Introduction

Energy conservation is the key aspect in all of our lives. As the population of any place increases, the main concern is the availability of energy, another is the availability of the water. Conservation of water resources is the main aspect that is of concern in water deficient cities. This paper speaks about those issues that aim at solving these two aspects such that they go hand in hand. The aim of this paper is to research about the various aspects of water level measurement and controlling the water level of the tanks and also on the different ways to ensure low power consumption in doing so. Also it reviews the various methodologies that involves water level measurement and the ways to present such data to the user.Water is a very precious entity and we must do our best to safeguard it. In homes, we manually turn

on the motor, seldom switching it off before it overflows. In most cases the overflowing of the water alerts us in switching the motor off. In many a times, we let it overflow for more than a few minutes. The amount of water that is wasted during such cases will grow to become a big wastage in the future times. Another disadvantage is that sometimes when we forget, we may end up with no water in our homes, in most dire situations. To avoid such cases, we need to have an automated method of filling the tank that is both beneficial, resource wise and energy wise. Hence we can save not only water but precious electricity.

There are 3 various approaches in this paper. One involves the research to find the near perfect Water level sensor for this application. The next involves various types of user interfaces and the last involves various types of communication protocols. This paper will cover the following:- What are the different methodologies followed to measure water level, what are the advantages and disadvantages of them? What are the various methodologies used to transmit data? Why choose wireless over wired and finally how and what is the optimal mode of wireless transmission.

Figure 1 shows the flow chart of a typical water level measurement and control system. As per the flow chart a typical water level measurement and control system will have level measurement sensors, a controller unit and the communication unit. The data from the sensor is sent to the controller unit which determines if the level of water is high or low, i.e. whether the tank is full or empty. If the tank is empty the controller will start the motor to fill the tank and once the sensor gives the signal that the water tank is full the controller turns off the motor. The wireless communication unit sends the signal back and forth from the sensor to the control unit. The user also receives the message from the control unit indicating the proper functioning of the entire system. If there is any fault in the system the user will get a notification and adequate measures can be taken to restore the system.

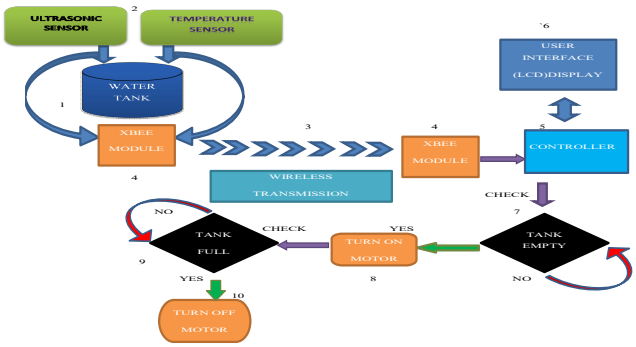

Fig. 1: A schematic flow chart of a typical water level measurement and control system. Description :- 1) Water Tank 2) Sensors 3) Method of transmission(wireless) 4) Wireless Device 5) Controller 6) Display Device 7) Decision Device 8) Motor Control 9) Decision Device 10) Motor Control.

II. Water Tanks

As water is a precious resource, we must ensure its proper utilisation. There are many ways to utilise water properly, like using limited water for all purposes and not having a running shower, rain water harvesting and so on. One of the most common water wastage is the over-flowing of the water tanks. Overfilling of tanks is not only messy due to the water going onto the roofs or going to the ground and stagnating and causing water-borne problems, it also is a loss in this modern world.We are water-starved and we need to preserve as much water as we can.

There are different types of water tanks and in different sizes. Our main purpose of building such tanks is to create a space for water to be stored safely such that we can use it when we want and also to increase the pressure of water. Also to store water in places where we cannot access groundwater. Another use of these water tanks is in resorts, where there are large no. of houses (more than 20) in which, it is easier to build individual tanks than to supply each directly. Hence in this case, we can use the ZigBee technology and the principle of wireless sensors to have a check on each of these tanks.

A water tank is a container for storing water. The stored water can be used for drinking, fire suppression, irrigation, agricultural farming, industries, household uses as well as many other applications.This essential purpose of providing clean essential water for various purposes is why we need water tanks and ensuring an efficient management of such tanks is very important.

The main types of tanks are,Ground water tank and Elevated water tank. The Ground water tankare surface water tanks made by digging the ground and is used to store large inventory of water to be used during peak demand cycles.

Elevated Water Tank also known as a water tower are tall structures which have a water storage on top of them. An elevated water tower on account of their height from the ground will create pressure at the ground-level outlet due to gravitational force acting on the water.

III. Water Level Measurement

Water level measurement data is very important in hydroelectric power plants, irrigation systems, flood warning systems etc. [I]. It is also quite useful in homes as this can reduce the wastage of water due to untimely switching on and switching off of the motor. Usually it is done manually, but this may not be effective because of human error, inaccessibility of the measurement site, etc. [X]. An automatic water level measurement system is needed to get the data continuously and as per the need and also to prevent the difficulties when one does the measurements manually. The classification of water level measurement can be done on the basis of various factors, such as, Contact, Type and Measurement.

Contact: Under the category of Contact, we have two different types, Contact and Non-Contact.Contact type of sensors arethose which come into the contact of water, namely interact with the water to determine the water level, and the other kind

is non-contact type sensors that do not come in contact with the water.There are various advantages with using contact sensors, being that they are more cheap, easy to assemble, and are easily available, low complexity. Their disadvantages outweigh being that, they have big losses, are not simultaneous, being they give output as specific points, The major disadvantage is that they are more-likely to pollute the water, or are to get polluted by the water, thus their reading gets less accurate as the device is being used. This causes error in measurement and must be replaced or repaired regularly. The examples for the various types of contact sensors are:- Mechanical and Electrical. Mechanical contact sensors use a floating buoy that rises or sinks with the level of water thereby rising or falling of the arm holding the buoy giving the level of water. The Electrical Contact sensors are based on 4 types. In the first case, wires of different lengths are cut and placed in the tank and when water flows at different heights, the different wires conduct, giving us the level of water at those heights. Next is Resistive, where the change in resistance of a material with the level of water gives us the water level. Next is capacitive sensors where the change in the level of water brings about a change in the level of capacitance. The last is the Inductive sensors, where the level of Inductance varies with the Level of water. In all these, they are dependent on the chemical nature of water and hence are in-accurate, as the chemical composition of water is not constant.

Non – Contact measurement sensors are those type of sensors that do not come into contact with the level of water. There are minimally polluting and the sensor, lies above or on the level of water. They have higher efficiency,maintain a stable output, may be simultaneous, wherein the give us the level of water at every instance of time and not only at specific heights. They can also be used independent of the liquid composition. They are a bit more complex, a bit costlier to use that contact level sensors , but their advantages of being more stable, more adaptable, more accurate, simultaneous level measurement and more advanced than the primitive contact level sensors leads us to the conclusion that these non-contact sensors are better to use than contact sensors. The examples of Non-contact sensors are Ultrasonic sensors, RFID sensors and Optical sensors. Ultrasonic sensors emit a pulse of ultrasonic waves and note the time they take to return back. The time gives us the level of water as the speed of ultrasonic waves in water and air is different. The RFID sensors are kept at fixed levels and a floating reader, alerts when it reads the card at each level. The Optical sensors employ a led, mirror and a photodetector, where the led and detector are fixed, whereas the mirror floats. The difference in intensity or time taken will give us the level of water. [I, II, VI, X, XII, XIV]

Measurement: We have level measurement and simultaneous measurement. Under Level Measurement, we can only measure the level of water at specific pre-determined levels. This enables us to only find-out the water level at specific points. We will not be able to find the exact water level at any given time. The instruments used for level measurement are RFID, wire. The other type of sensors include simultaneous level sensors, where the water level is found and reported continuously, the advantage is to monitor the water level at any time. This is also a universal type of sensor, where the same sensor can be used for tanks of various dimensions. Hence it

is more useful in places where there are tanks of different sizes, same instrument can be purchased. Also another advantage is the continuous monitoring of water level for industries.

Type:We have mechanical float type sensors that include a mechanical arm that is attached to a buoy that floats. A mechanically actuated float opens or closes a switch as it moves across when the level of water rises or drops. The switching occurs as a result of the movement of the float against a switch.

The next category of sensors includes Electrical sensors: These maybe of conductive, capacitive, inductive or resistive type. In conductive liquids level detection can be done by conductive level sensors. A low voltage, current limited power source with separate electrodes is used for conductive level sensors. Two wiresof different lengths are inserted in the water tank. The longer wire touches the base of the tank while the shorter wire is placed at the top of the tank in such a way that it is just below the lid of the tank. When the tank is empty there is no current flowing through the circuit and the motor is switched on. When the water starts filling and reaches the top of the tank the shorter wire comes in contact with the water and the circuit is completed, which then indicates the motor to stop pumping the water. [VI]

The capacitive level sensor that detects a change in the capacitance to give the level of water. The sensors can sense material with varying dielectric constants from low to high. The sensor contains two electrodes and the dielectric liquid whose level is to be determined is placed in between the electrodes. When the level of the liquid changes the capacitance also changes and by measuring the capacitance one can determine the level of the liquid. There are no moving parts, and can be designed for high temperature and pressure applications. [II, XIII]

The inductive sensor,uses two circular coils of different radii. The inductance of the coils is proportional to the conductivity of the medium like water and the angular frequency and has a nonlinear relation with the height of water. Thus using this relation we can find out the level of water by accurately measuring the inductance of the coils.[XIV]The resistive type of sensor is used to find the level of water by measuring the resistance of the water and thereby relating it to the water level.

The next type of sensors is Optical sensors: Optical sensors are used for point level sensing. These sensors measure the time required for the reflected light from the surface of the liquid to determine the height or level of the liquid. The time required for the reflected light to hit the water surface and return to the detector is measured precisely to determine the range or distance of the surface from the sensor. [XII]

Another type of sensor which uses acoustic waves to detect the level of water is ultrasonic sensors. Ultrasonic sensors are of non-contact type. The ultrasonic transducer emits high frequency (20 kHz to 200 kHz) acoustic waves. The waves travel through air and are reflected from the surface of water. Ultrasonic sensors can

provide continuous monitoring of the water level. The ultrasonic sensor ismore widely used due to low price and high functionality[XII].

The ultrasonic sensor has a transmitter and receiver. Ultrasonic wave travel in the air with the velocity of 340 m/s (sound wave velocity), touch the water surface and is reflected back to the sensor. The time taken by the wave to travel from the sensorto the water surface and back to the sensor is used to determine the distance of the water surface from the sensor.

Table 1 gives the comparison of the various sensors. From the table it is clear that ultrasonic sensors have the best features. It is a non-contact type sensor has high adaptability, low energy consumption and a fast response. The optical sensors also have similar features but the optical sensors alignment of the sensors is a big challenge. Slight deviation in the alignment can give errors in the measurement.

Table 1:Comparisontable for the different sensors [I, IV, VI, IX, X].

Parameter	Ultrasonic	Electric	Mechanical	Optical
Type	Non-Contact	Contact	Contact	Non-Contact
Measurement	Simultaneous	Both	Both	Simultaneous
Error %	<5%	Inductive 2% Capacitive 5mm	-----	0.5mm or 2%
Adaptability	Yes	No	No	Yes
Energy Consumed	Low	Low-Medium	Low	Low-Medium
Complexity	Medium	Low	Low	Medium
Output	Linear	Non-Linear	Linear	Linear
Response	Fast	Medium Fast	Slow	Fast

IV. Method of Transmitting Data

Until now, we have discussed the methods of detecting water level. This data needs to be communicated to the Controller. This can be done in two ways. Wired communication and Wireless Communication. Wired Communication involves the use of wires such as Co-axial cables, Ethernet cables, Optical fibers and so on to transmit the data. As we need to transmit the data over long distances (1Km) the attenuation losses and cost of the wires and the pathway that must be paved to implement such cables will ensure a huge cost. Also when we go for multiple sensors such as 5-10 such sensors that try to communicate with the controller, the cost also is multiplied. This when compared to the cost of implementing wireless sensors is almost 1/10th of the cost that may be incurred when using wired methods of transmitting. They have a limited mobility. If we were to switch the location of the controller, the connections are needed to be laid out again. This does not occur when using wireless communication. This makes us go in search of other methods of transmitting data such as Wireless mode of transmission where the data can be

transmitted over the same distance at lower costs. The only drawback maybe that the data-speed maybe less than that provided by the wired networks.Also the interference may be higher due to noise.[VII]

Thus due to the advantages of high mobility, broadcast nature, Easy installation of wireless communication, we adapt the same for our discussion. Wireless communication involves transmission of data from transmitter to receiver without using any wires with the air as the medium. It can be using Radio waves or using microwaves. There are many different classifications of wireless communication, with varying protocols, but the most widely or popularly used are the following:-

- GSM
- WIFI
- UWB
- BLUETOOTH
- ZIGBEE

GSMThe first method is GSM, it stands for Global system for mobile Communication. It involves communication between two systems using mobile. It uses a SMS (Short Message Service) to send a message directly to the user regarding the status of the sensor. A GSM Modem such as SIM300C is used to send the SMS to the user's Mobile Handset. Here the disadvantage is that the mobile carrier charges will be applicable to send the SMS messages. Hence to send multiple messages in a single day implies the user has to bear the cost[X].

WIFI refers to Wireless fidelity. It works under the Protocol IEEE 802.11. It has a maximum signal rate of 54Mbps. It has a nominal range of 100m and has a channel Bandwidth of 22 MHz. It has a Power consumption of 15-20 dBm. It can have upto a maximum of 2007 nodes. Due to all of the above features Wi-Fi is a suitable method of transmitting Data. Its Advantages are High Speed and Large no. of nodes. It is also low power, but the cost of a Wi-Fi module and the cost of data usage is higher when compared to the other modes. It also has higher code complexity, is difficult to transmit data. It is limited to a maximum distance of about 100m. [III]

UWB refers to Ultra-wideband (UWB)is an indoor short-range high-speed wireless communication.UWB has a bandwidth of over 110 Mbps (up to 480 Mbps). But it only has a nominal range of about 10m, Consumes higher power when compared to Wi-Fi, and is restricted to a maximum of 8 nodes. It is hence useful for in-house sensors and high speed requirements and is not of good use in large distance sensor communication.[III]

BLUETOOTH is wireless standard technology for exchanging data over short distances. Bluetooth operates in the range of 2400–2483.5 MHz. Bluetooth technology is included in many of the products currently available in the market like mobile phones, tablets, laptops, some high definition headsets, modems, and smart

watches etc.[XI] Bluetooth is a well advanced method of communication and by far the simplest and least complex method of communication. But the major limitation of Bluetooth is the range that it covers. Even low-power is not as big of a problem with Bluetooth 4.0, yet it can cover a nominal distance of only 10m and hence is not suitable for long range (1km) communication.

ZIGBEE:ZigBee is a high levelwireless technology using low-power radios. It is based on an IEEE 802 standard for personal area networks. It is used in wireless mesh networks. ZigBeeismostly used for transmission of periodic or irregular data from a sensor or input device. The low cost and low power allows the technology to be widely used in wireless control and monitoring applications. [VIII], [V] Figure 2 shows the picture of a ZigBee Module.

Fig. 2: A picture of the ZigBee Module.

Advantages of ZigBee:

ZigBee is simple to implement and has very low power consumption, because of which batteries will last longer for months to years. It can be used in a mesh network and can support a large number of nodes. It can be easily controlled and monitored remotely. Thus it is ideal for water level monitoring and control systems.

V. Discussion

Water level monitoring and control systems are essential to reduce the wastage of water due to overflowing of tanks or reservoirs. As the population of the world is increasing the demand for potable water increases and hence it is important to get solutions which will reduce the wastage of water. In this paper we have discussed the different storage methods, compared the sensors used for water level monitoring systems and the wireless communication technologies. It is found that the ultrasonic sensors are the most suitable sensors for water level monitoring systems. Ultrasonic sensors are low cost, and easy to install and has low maintenance. For wireless, ZigBee is the most suited technology as it is also low cost and low power.

VI. Conclusion

In this paper we have surveyed the water level measurement and controlling systems. The various types of water tanks, the various methods of water level measurement, why water level measurement is needed. Which is the best and low-power approach to measure water level, the methods of sending and receiving

data,why to choose wireless communication over wired and the different methods of wireless communication and the advantages ofZigbee method of sending and receiving data.

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