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Design and Development of an Automatic Pump Switcher Using Ultrasonic Level Sensor, Contronix Controller and GSM Module

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Abstract
This project presents the design and development of an automatic pump switcher system using Siemens ultrasonic level sensor, Contronix control module, and GSM module. This system will be designed to automate the operation of water pumps in overhead tanks or reservoirs, ensuring efficient water management and reducing manual intervention.
This proposed system will offer a reliable and efficient solution for automatic pump control, and this will make it suitable for different types of applications that include industrial, commercial, and residential applications for water management systems.
Siemens Ultrasonic level sensor will measure water level in the tank and send a 4-20mA signal to the Contronix module, depending on the level in the tank, the level sensor will initiate the relay and Contactor to switch the pump(s) on or off.
The Contronix control module will process sensor data and control the pump operation. The contronix module also provides users with an interface display which is used for programming control parameters and for monitoring real time liquid level locally.
The GSM module will enable remote monitoring and control of the system via SMS providing users with real-time information.
The proposed system will prevent water overflow, conserve electric energy by switching off the pump in certain appropriate conditions, notify the user about the water level through an SMS alert or mobile app and last but not least to prevent the pump from running dry, thereby enhancing the longevity of the pump.

Keywords: Contronix, Siemens, 4-20mA, GSM, SMS

1. Introduction

1.1 Background of the Study

According to (Souvik Deb, 2018), our world and community are facing excessive water usage either for domestic or commercial purposes and it is a serious issue, as it affects the sustainability of our environment. Water is one of the scarce natural resources, therefore, it is important to properly use and manage our usage in different sectors especially in those places which are known for low-drinking water supplies like Middle East and North African countries. There is a need to monitor the water usage in different sectors such as residential, agricultural, commercial and industrial areas.

Nowadays, there is a lot of study to conserve our natural resources such as energy and water. Water and energy conservation techniques and technological interventions are important to attain sustainable solutions to our environment that is currently at risk due to excessive use of such natural resources being accelerated by the increase in population, human demand and economic growth.

According to the United Nations (UN) report, almost half of the world's workers work in water-related sectors showing that most of the jobs are dependent on water. Therefore, investments that enable proper water usage mechanisms or technologies will have significant impact on sustainable development. One of the factors that diminish the accessibility of enough water is climate change that also arises due to the excessive use of non-renewable energy sources such as fossil fuels. As water is needed for energy production, energy is also needed for production, transportation and distribution of water. Water is a limited resource and it is very essential for agriculture, industry and also for creatures' existence on earth including human beings. Every living thing on earth needs water to survive.

Human bodies are made up of more than 70 percent water. The main use of clean water is to drink, grow crops for food, operate factories, and for swimming, surfing, fishing and sailing. Mainly water is wasted by human beings by many uncontrolled ways. So, we have to control the pumping system with a perfect way to prevent the wastage of water. By using automatic pump controlling system, we can avoid the wastage of water, power consumption and easily prevent the water for our future generation.

Automatic water pump switchers can be used to avoid overflowing and controlling the level of water in the tank. This pump controlling system implementation makes potential significance in home applications as well as big industries. The method of pump control for home is simply to start the feed pump at a low level and allow it to run until a higher water level is reached in the water tank. And when the water level reaches the predetermined point, the pump will stop and no water will overflow. This control system is widely used for monitoring of liquid levels, reservoirs etc.

1.2 Motivation of the Study

The primary motivation for this project, the automatic water pump switcher, is to improve efficiency, reduce energy consumption, and minimize water wastage. These systems automate the on/off switching of water pumps based on water levels, eliminating the need for manual operation and preventing overfilling or running pumps dry. This leads to significant cost savings, reduced wear and tear on pumps, and contributes to better water management and conservation.

1.3 Significance of Study

This project is significant for its ability to automate water pump operation, ensuring an efficient water supply and preventing damage to the pump. It eliminates the need for manual switching, offering convenience and conserving energy by only operating the pump when needed.

Below is a breakdown of the significance of this study:

1.4 Automated Operation and Convenience

Automatic controllers eliminate the need for manual monitoring and switching of the pump, saving time and effort. They activate the pump based on pre-set parameters like water level, pressure, or flow rate, ensuring a consistent water supply without manual intervention. This is particularly useful in homes, agriculture, and industrial settings where a reliable and consistent water supply is crucial.

1.4.1 Energy Efficiency and Cost Savings

By only running the pump, when necessary, automatic controllers minimize energy consumption, leading to lower electricity bills. They prevent the pump from running dry, which can cause damage and require costly repairs. Reduced energy consumption also contributes to a smaller carbon footprint.

1.4.2 Enhanced Pump Protection

Automatic controllers can be programmed to detect low water levels or pump overload, automatically shutting off the pump to prevent damage. This "dry run protection" feature is especially important in well systems where the pump could be damaged if it runs without water. Overload protection prevents the pump from running for extended periods under high load, which can lead to motor burnout.

1.4.3 Consistent Water Pressure

In systems where consistent water pressure is needed, such as in residential plumbing or agricultural irrigation, automatic controllers can be configured to maintain a stable pressure range. This ensures an adequate water supply for various applications without fluctuations.

1.4.4 Versatility and Adaptability

Automatic pump controllers can be used in a wide range of applications, including residential water supply, agricultural irrigation, industrial processes, and more. They can be tailored to specific needs by adjusting parameters like water level, pressure, and flow rate. Advanced models offer features like remote monitoring and control via mobile apps, further enhancing their versatility.

1.5 Scope of Study

This study is limited and concentrates on the design and development of an automatic water pump switcher; it discusses system architecture, the operation of individual components, and a detailed description of how to automate the process of turning a water pump on and off based on water levels in a tank.

1.6 Statement of the Problem

This system will mitigate problems such as poor water allocation, energy wastage, and lack of adequate and integrated water management. Also, issues of inefficiency and human error associated with manually operated pumps will be addressed. These systems aim to automate the process of refilling water tanks, optimizing water usage, and preventing issues like overworking the pump or water wastage.

This project develops an automatic liquid pump switching system that utilizes a Siemens ultrasonic level sensor to monitor liquid levels, a Contronx Controller to receive the signal from the ultrasonic level sensor and switch the pump, and a GSM module for remote control. It is very useful because the user need not worry about the water content during the peak hours of the day. It not only helps in the daily chores but also prevents water wastage. It reduces human labor, saves time, and also keeps the user updated regarding the water content.

1.7 Objectives

1.7.1 General Objective

The primary objective of this study is to Design and develop an automatic pump switcher using ultrasonic level sensor to monitor liquid levels, Contronx Controller to receive the signal from the ultrasonic level sensor and Switch the Pump and a GSM module for remote control.

1.7.2 Specific Objectives of the Project

1. To Design and develop an automatic water pump switcher
2. To mitigate wastage of water and reduce wastage of electric energy
3. To reduce human intervention in the water pumping system.

2. Overview

An automatic water pump switcher, also known as an automatic water level controller, is a system designed to automate the process of filling and maintaining water levels in tanks or reservoirs, eliminating the need for manual operation. These systems typically utilize sensors to monitor water levels and a control circuit to activate or deactivate the water pump as needed. The literature on this topic spans from basic circuit designs to more advanced microcontroller-based systems, with a focus on efficiency, reliability, and cost-effectiveness. Here are key aspects explored in this project.

2.1 Basic Circuit Design

Early approaches focused on using simple electronic components like 555 timer ICs to create a basic on/off control for the pump based on water level sensors. These designs often involve relay circuits to switch the pump and incorporate safety features like emergency stop switches.

2.1.1 Sensor Technologies

Various sensor types are used, including float switches, pressure sensors, and capacitive sensors, each with its advantages and disadvantages in terms of cost, accuracy, and reliability.

2.1.2 Microcontroller-Based Systems

More advanced systems utilize microcontrollers to implement sophisticated control logic, allowing for features like variable speed control, data logging, and remote monitoring.

2.1.3 System Implementation

Literature often covers the practical aspects of building and implementing these systems, including selecting appropriate components, designing enclosures, and ensuring proper installation and wiring.

2.1.4 Performance Evaluation

Studies evaluate the performance of automatic water pump switchers, including factors like water level accuracy, pump activation/deactivation times, and energy consumption.

2.2 Literature Review

The daily routine starts with water; it is one of the basic needs to survive. People depend on overhead or underground tank for their daily usage. Overhead tanks are usually made of opaque material to prevent algae growth and are closed with lid to prevent from dust and mosquito infestation.

So, the water level present in the tank is unknown. Many times, we switch on the motor and forget to turn off, because of this most of the water will be wasted unknowingly. This leads to water scarcity. So, there is need for alternatives which can automatically monitor the level of water in the tank.

Water level monitoring is commonly used in some of the applications like Flood monitoring, River level monitoring, Groundwater monitoring, Surface water monitoring etc.

Clean water is essential to sustain life and quality of water plays a vital role in the well-being and health of human beings. The objective of this chapter is to review some automatic water level monitoring and pump control systems and some water level sensors.

2.2.1 Review of Related works

1. Deepiga (2019) proposed a prototype using microcontroller, pH and turbidity sensor. The water level was indicated using LEDs and this was done automatically by the controller. Water quality was tested by pH, turbidity, temperature sensor in real time and was monitored by agent. For leak detection in water pipes force sensitive resistor (FSR) was used.
2. Praseed *et al* (2019) proposed a liquid level monitoring system using electromagnetic valve, float sensors, MATLAB, LABVIEW to maintain liquid level close to the reference level. The restrictions imposed by configuration and working of float sensor led to non-achievement of control of 2 levels.
3. Muthamil *et al* (2018) developed an automatic water level indicator using Arduino, ultrasonic sensor and GSM. The water level was sensed by ultrasonic sensor and accordingly the motor was switched on and off automatically, SMS alert was sent to user.
4. Jatmiko *et al* (2019) built a water level detection system using ping sensor, microcontroller AT89S51. The water level was measured by ping sensor and the data was sent to receiver module by transmitter module via wireless communication.
5. Charles *et al* (2018) develop a prototype using ultrasonic sensor, node MCU, LABVIEW. Ultrasonic sensor measured water level. The sensed value was sent to Google cloud platform by node MCU. In the LABVIEW front panel the webpage was accessed and accordingly the water level was monitored by adjusting the valves.
6. Lukman *et al* (2019) developed a system using ATMEGA328, ultrasonic sensor, buzzer, Xilinx. Three tanks were utilized with corresponding ultrasonic sensors. Arduino was the controller. When system was turned on water flows through tank1 after, that tank2 was filled and buzzer was on to indicate two or more tanks are filled. Next, tank3 was filled until level indicator controller detects it and water supply was stopped. Thus, water wastage was prevented. The same was also designed and executed on FPGA using Xilinx ISE. FPGA has proven more advantageous for automated multiple water tanks over microcontroller.
7. Khaled *et al* (2018) developed a water level sensing and controlling system using PIC microcontroller and water level sensor. The water level sensor was designed, the level was detected and was sent to microcontroller which processed the data and further action of pumping was done. In addition, web-based water level monitoring was achieved.

2.3 Review of Different Water Level Sensors

There are different types of water sensor that are used as water level measurement sensors included robust ceramic pressure sensors, shaft encoders, acoustical sensor, and the visual reference staff gages. Stevens still offers the low-powered, mechanical chart recorders for a long-term uninterrupted, real-time chart of water level (Siddartha, 2018).

2.3.1 Pressure Sensor

Pressure sensors are submerged at a fixed level under the water surface. The pressure sensor measures the equivalent hydrostatic pressure of the water above the senor diaphragm. It is like weighing the water.

Applications

a) Ground water level monitoring
b) Ground water slug testing

1. Advantages of Pressure Sensors in water level measurements
   a) Output can be analog or digital depending on model

   b) Smaller diameter stilling well or pipe can be used for installation
   c) A low-profile installation site can be achieved using pressure sensors with internal data logging.
   d) Easy to install, maintain and calibrate.
2. Limitations of Pressure sensors in water level measurements
   a) Typically, subject to long-term drift and variations with temperatures.
   b) However, they are in the water where the temperature is usually fairly stable, so the temperature concern may not be too high. It is good idea to check calibration every 6 months.
   c) Fouling or corrosion with direct exposure to the water can affect the readings.
   d) Models are available in a broad pressure range that needs to be known at time of purchases.
   e) Some models require breather tube in the cable to reference to atmospheric pressure for best accuracy.
   f) Some models have a sensor head that can be easily damage to human touch or other objects touch.

2.3.2 Encoders Float

Stevens carries a number of encoders, potentiometers and linear variable differential transformers that are used in liquid level measurement applications. These devices are float-operated sensors that utilize a float and counter-weight attached to a line placed around the Shaft Encoder's pulley. As the liquid level changes the float moves up or down, moving the pulley. The shaft encoder turns the angular position of the pulley and shaft into an electronic water level signal that can be logged by an attached data logger (Siddartha, 2018).

2.3.3 Shaft Encoders

A shaft encoder is an electro-mechanical device used to convert the angular position of a shaft or axle to an analog or digital electrical signal. These devices are used in many applications including liquid level measurement. Part of the mechanical aspect of this device for level measurement utilizes a float and counter-weight attached to a line or tape placed around a pulley attached to the encoder's shaft.

As the level changes, the float moves up and down and, thereby, rotating the pulley and the attached shaft – generating an electronic wave form for both rotating direction and amount. By converting shaft rotation into electronic signals, encoders are used to electronically monitor the position of a rotating shaft. There are two main types of encoders for liquid level measurements are absolute and incremental.

1. Advantages of Float-operated sensors for water level measurements
   a) Since many older sites were designed for mechanical float operated
   b) Measurement, encoders are easily adapted to existing float gear and gauging system.
   c) Float-operated systems are easy to understand and troubleshoot.
   d) Most encoders offer good temperature stability.
   e) Various electronic technologies can be used including digital incremental and digital absolute (encoders); analog absolute (potentiometers and Linear variable differential transformers); or digital absolute (synchros).
   f) Float is protected in a stilling well and sensor is not in direct contact with the water. Therefore, the risk of damage is low from debris flow or fouling.
   g) Highly accurate with large sized floats.
2. Limitations of Float-operating sensors in water level measurement
   a) Requires a stilling well to assure stability and reliability of the float
   b) Rapid changes in water level may result in the cable / tape line becoming disengaged from the float-operating sensor's pulley.

2.3.4 Non-Contact Water Sensor

Both ultrasonic and sonic level instruments operate on the basic principle of using sound waves to determine fluid level. The frequency range for ultrasonic methods is ~20-200 kHz, and sonic types use a frequency of 10 kHz. A transducer directs sound waves downward in bursts onto the surface of the water. Echoes of these waves return to the transducer, which performs calculations to convert the distance of wave travel into a measure of level. For practical applications of this method, you must consider a number of factors (Henry Hopper, 2018).

1. Applications:

Ultrasonic Sensors are frequently used in:
   a) Water level measurement with the sensor attached to a bridge or structure directly over the water.
   b) For flood applications to avoid damage from debris flow
2. Advantages of ultrasonic sensors for water level measurement**:**
   a) Non-contact sensor allows for easy installation on a bridge or structure over the water.
   b) Non-contact sensor reduces the problem of sensor fouling or corrosion. Also, potential damage from debris is reduced.
3. Limitations of ultrasonic sensors for water level measurement:
   a) The speed of sound through air varies with the air's temperature. The transducer may contain a temperature sensor to compensate for changes in operating temperature. However, this only takes into account the temperature at the sensor, which may be different as the sound wave approaches the water.
   b) Debris, extreme turbulence or wave action of the water can cause fluctuating readings. Use of a damping adjustment in the instrument or a response delay may help overcome this problem.
   c) Maximum distance to the water level surface is typically 9 meters or less.
   d) Limited usage in shallow streams or in streams with very high velocities with minimum depth requirements.
      Very high concentrations of fine sediment in suspension can scatter and absorb the sonic pulse, preventing reflection of a detectable echo.
   e) Ultrasonic typically require more power than other water level sensors.
   f) Build-up on the sensor head, even simple condensation, can cause problems with the sensor operation.

3. Methodolody

3.1 Overview

This chapter describes the methodology used in the design and development of the automatic water pump switcher. It covers the research design, system construction, component selection, programming, and the operational description of the major components used in the project.

3.2 Research Design

The research design for this project is primarily developmental and experimental. It involves:Component Selection: Researching and selecting appropriate components based on specifications, cost, and availability. Key components include the Siemens ultrasonic level sensor, Contronix control module, GSM module, relays, contactors, and power supply units.

3.2.1 ystem Architecture Design: Developing a block diagram and schematic to illustrate the interconnections and data flow between all components. The system architecture is shown in Figure1.

3.2.2 Programming Logic Development: Formulating the control logic for the Contronix module to process sensor input and control the pump accordingly. This includes defining set points for high and low water levels and configuring the GSM module for communication.

3.3 System Construction and Assembly

The physical construction of the system involves the following steps:

Mounting the Siemens ultrasonic level sensor securely on the wooden board, ensure a clear path for ultrasonic waves to the target surface.

- Assembling the control panel housing the Contronix module, GSM module, relays, contactors, terminal blocks, and power supply.
- Executing all electrical wiring as per the developed schematic

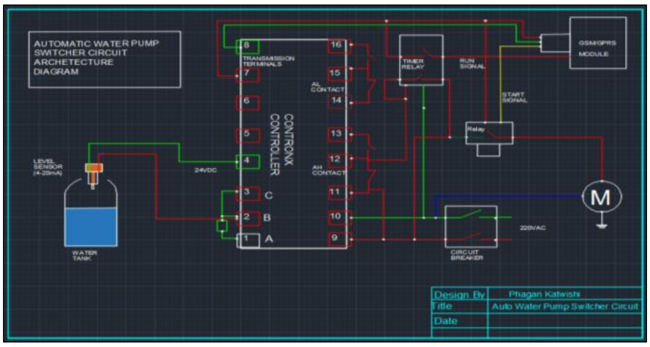


Fig 1: System Architecture

Table 1: Major components and specifications

Component	Model/Type	Key Specifications
Ultrasonic Level Sensor	Siemens7ML5221-2AA11	Range: 0.15m - 8m, Output: 4-20mA HART, Supply: 12-30V DC, Accuracy: ±0.15%
Controller	Contronix CH6	Inputs:4xAnalog(4-20mA), Outputs:4xRelay, Display: LCD, Supply: 24V DC
GSM Module	SIM900A	Quad-Band 850/900/1800/1900MHz, GPRS multi-slot class 10/8, Supply: 5V DC
Power Supply	Mean Well DR-120-24	Output: 24V DC, 5A, Input: 100-240V AC
Contactor	CHINT NXC-25	Coil Voltage: 24V AC/DC, Current Rating: 25A

3.4 Level Sensor Mounting Precautions

The ultrasonic level sensor must be mounted correctly to ensure accurate measurements. Key precautions include:

1. A hole was drilled in a mounting board, and the Siemens ultrasonic sensor was fixed in place.
2. The sound path was perpendicular to the target surface.
3. It was clear of obstructions like inlet pipes or ladders.
4. It was away from high-voltage wiring to avoid interference.

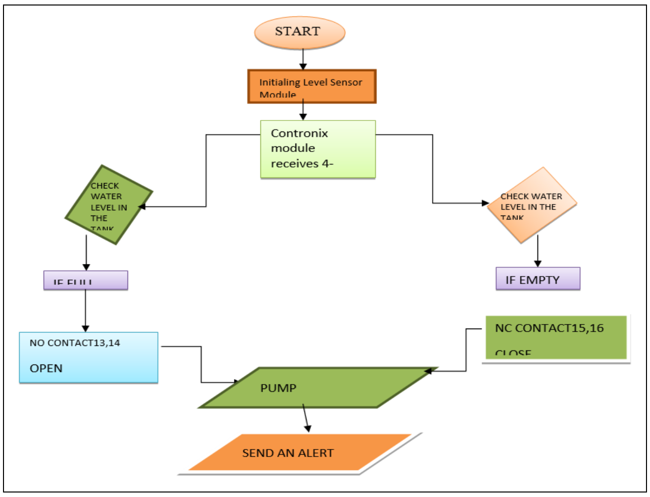
3.5 Wiring

All control components (Contronix controller, GSM module, timer relay, contactor, terminal blocks, and power supply) were mounted on a DIN rail inside an electrical enclosure.

Wiring was executed as per the system schematic:

1. Power Circuit: 220V AC supply was connected to the main power supply unit and the contactor's main terminals.
2. Sensor Loop: The 24V DC power supply was connected to the Siemens sensor, creating a 4-20mA current loop. The sensor's output wires were connected to the analog input terminals of the Contronix controller.
3. Control Circuit: The relay outputs from the Contronix controller were wired to the coil of the timer relay. The timer relay's output contacts were then connected in series with the GSM module's relay and the coil of the main pump contactor.
4. Pump Circuit: The dummy pump in form of a light bulb was connected through the main power contacts of the contactor.

Intelligent Processing: The device uses features like Auto False-Echo Suppression and Sonic Intelligence to filter out interference from tank walls or other obstructions, ensuring accurate readings. The measured level is outputted as a continuous signal; 4-20 mA current loop. In order to achieve accurate water level measurement, a list of parameters for the level sensor, contronx controller and gsm module should be programmed.



4. Conclusion and Recommendations

4.1 Conclusion

The project successfully designed, developed, and implemented an automatic water pump switcher using a Siemens ultrasonic level sensor, a Contronx controller, and a GSM module. The system met its core objectives:

1. It automatically controls a water pump based on precise level measurements.
2. It effectively prevents water overflow and protects the pump from dry running.
3. It provides remote status updates via SMS, reducing the need for manual checks.

The performance analysis confirms that the system is accurate, reliable, and suitable for practical deployment. The use of industrial-grade components ensures longevity and stability.

4.2 Recommendation

1. For widespread adoption, a cost-benefit analysis should be conducted to demonstrate the savings in water, energy, and maintenance costs.
2. The system should be encapsulated in a proper weatherproof and dustproof enclosure for outdoor installation.
3. Users should be provided with a simple manual for basic troubleshooting and understanding of the system status indicators.
4. Future developers should consider the proposed enhancements, particularly IoT integration, to increase the system's functionality and appeal in the modern smart infrastructure landscape.

4.2.1 Future enhancements

The current system is functional and robust, but it can be enhanced with the following features in future iterations:

The project can also be installed with pH sensors which will help to regulate the acidity or alkalinity of the water.

1. IoT Integration: Instead of SMS, data could be sent to a cloud platform for real-time graphing, historical data analysis, and control via a web dashboard or mobile app.
2. Multi-Tank Control: The system could be scaled to monitor and control pumps for multiple tanks.
3. Flow Meter Integration: Adding a flow meter could provide data on water consumption and detect leaks.
4. Solar Power Compatibility: Integrating a solar PV system with a battery backup would make the system ideal for remote, off-grid locations.
5. This project can also incorporate automatic control of water tank level using PID; the hardware can be equipped with a frequency converter, level meter, PLC programmable controller, frequency conversion motor and operator workstation. The Operator will be required to set the water storage tank level height using the work station, to ensure that the water storage tank is not empty, and prevent the damage that comes with running the pump dry. PLC detects the actual level of the water storage tank, through the PLC internal PID calculations, and then outputs speed signal to the frequency converter, which in turn adjusts the speed of the motor and the water pump, in order to ensure that the level of water storage tank is always the same as that of the workstation set valuable.

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