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Development and Implementation of a Solar-Powered Smart Level of Water Monitoring System in Nigeria

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ABSTRACT

This research delves into the configuring and construction of a solar system for smart level of water observation which would provide an efficient and cost-effective alternative for level of water observation in rural areas. It consists of a solar panel, a controller, a level of water sensor and a pump. The system would observe the level of water in a tank and automatically switch on or off the pump, according to the level of water. The system was designed using a microcontroller and different components such as solar panel, sensors, and relays. The prototype was tested to determine its performance and accuracy, showing results of the system being able to accurately observe and control the level of water in the tank. Also, cost analysis showed that the system was cost-effective and could be constructed in rural areas.

1. INTRODUCTION

Water is necessary for life and is an important resource for farming, industries and household. In many parts of the world, acquiring a good water source is limited because of its scarcity and uneven distribution[1]. This is especially true in off-gird locations where water is often insufficient and not evenly distributed. One of the main challenges faced by these areas is the lack of an efficient and accurate system for level of water monitoring[2].

The traditional approach to level of water monitoring involves manual monitoring of the level of water in a tank or reservoir. Apart from being time-consuming, this approach is prone to errors. To overcome these limitations, automated level of water monitoring systems have been developed[3]. These systems use sensors to know the level of water in a tank and control the supply of water. However, these systems are often expensive and require a continuous power supply[4].

To address these issues, a solar powered smart level of water monitoring system has been proposed. This system uses solar energy to power the system and observe the level of water in a tank. The system is designed to be cost-effective and reliable[5].

2. LITERATURE REVIEW

2.1 Solar Energy

Solar energy is very abundant and renewable sources of energy available. It is a clean and environmentally friendly source of energy. Solar can be used to generate electrical energy and to power various systems such as pumps and level of water monitoring systems. Solar energy is particularly suited for rural areas where there is limited access to other sources of energy[6].

Solar energy can be used to power various types of systems. These include photovoltaic cells, which turn solar power to electricity. Solar can also be used to power systems such as pumps and level of water monitoring systems[7].

2.2 Smart Pumping Systems

Smart pumping systems are automated systems that are used to control the supply of water. These systems use sensors to know the level of water in a tank and control the pump. Smart pumping systems can be used to reduce the amount of water used and to ensure that the water is used efficiently[8].

2.3 Level of water Monitoring Systems

Level of water monitoring systems are used to monitor the level of water in a tank or reservoir. These systems use sensors to detect the level of water and provide an indication of the level of water. This information can then be used to control the supply of water[9].

2.4 Solar Powered Smart Pumping and Level of water Monitoring System

A solar powered smart pumping and level of water monitoring system has been developed. The system consists of a solar panel, a controller, a level of water sensor and a pump. The system is designed to monitor the level of water in a tank and to automatically switch on or off the pump according to the level of water[10]. The system also includes a display that can be used to monitor the level of water. The prototype model has been tested to determine its performance and accuracy.

3. METHODOLOGY

3.1 System Design

The system was designed using a microcontroller and various components such as a solar panel, sensors, and relays. The system consists of a solar panel, a controller, a sensor for thelevel of water, and a pump. The system is designed to monitor the level of water in a tank and to automatically switch on or off the pump according to the level of water. The system also includes a display that can be used to monitor the level of water.

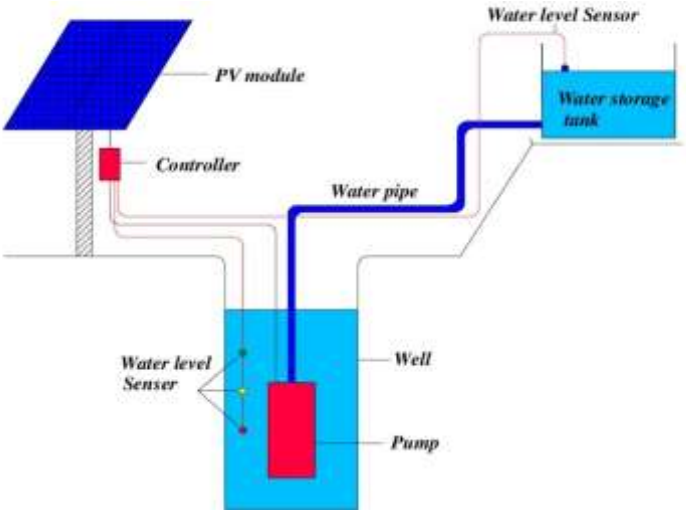

Figure 1: Schematic of the Solar Powered Smart Level of water Monitoring System

3.2 System Development

The system was developed using a microcontroller, sensors, and other components. The system was programmed to know the level of water in the tank and to control the pump accordingly.

3.3 System Testing

The system was tested to determine its performance and accuracy. The system was tested using a water tank and a level of water sensor. It was observed that the system was able to accurately observe and affect the level of water in the tank.

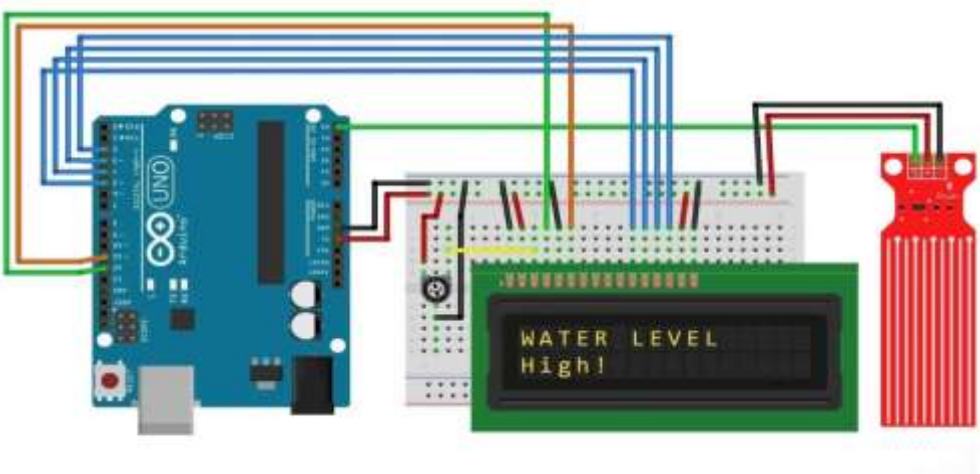

Figure 2: Level of water Detection Circuit

3.4 Relevant Regulation and Design Standards

The installation of the pv component must consider several factors in order to exploit solar radiation: the orientation, the inclination, latitude of the site, climatic conditions, and shade effect among photovoltaic panels. The proper consideration of these variables will assist in maximizing their energy production by being exposed for the longest possible duration to the maximum intensity of solar radiation.

3.4.1 Orientation

To compute how much energy a photovoltaic install can generate, the solar irradiation in the place to which the photovoltaic install corresponds and the path of the solar rays in that locality throughout all times of the year must be known. The height and azimuth of the sun determine the position of the sun at any given time.

The performance of pv panels is influenced by their direction and tilt (inclination), which is the level of prospective energy produced. Factoring in the inclination, solar power will be at its highest level when the plate's position is perpendicular to the radiation. The orientation of the photovoltaic module is stated as the angle of deviation from the geographical south of a surface or north in the southern hemisphere. A maximum deviation of ± 20° is permissible.

3.4.2 Inclination

The climatic circumstances of PV modules and their geographical position are important factors taken into consideration in the selection of a proper tilt for optimizing energy production. Surface solar radiation will always be greater if a surface is perpendicular to the propagation of solar radiation than in any other position. The inclination takes into account the sun's position in the sky over the year, so that its optimal placement can vary through the seasons.

3.5 Basic Features and Selection Considerations

Some basic features of the 2 Horse Power liquid control system are categorized under the following headings:

(i) Enclosure

(ii) DC water motor pump

(iii) Solar panels

(iv) Charge controller

(v) Cables

(vi) Protective devices

(vii) AC-DC converter/Step down power circuit (220 VAC-40V DC)

(viii) Arduino Microcontroller

(ix) Water sensor module (Float sensor module)

(x) Liquid Crystal Display (LCD)

(xi) Buzzer

(i) Enclosure

This is made up of 1500 x 800 x 300 mm of metal that protects the system constituents from external particles and curbs contact with parts of the system with high voltage, which is dangerous to the human body. The system has a cooling fan and is mounted by IEC 60529 - (IP code).

(ii) Electric Pump

Electric pumps are those powered by either the direct current from the batteries or solar energy to pump water to a storages tank or from boreholes. The Motorized pump works using 6, 12, 24, or 32 volts of DC power. Solar DC pumps use photovoltaic panels that produce direct current from sunlight exposure.

(iii) Solar Panels

Basically, solar panels sit in the sun and absorb the sun's rays; they generate electricity or heat. A collection of solar (or photovoltaic) cells converts solar energy into electricity through the photovoltaic effect. An array is formed by placing them in a grid-like pattern across the surface of the solar panels. This design uses a collection of 8 panels to achieve the desired output.

(iv) Charge Controller

The charge controller regulates the current and voltage supplied to the loads, while surplus power goes to the battery system line. Thus, the batteries can keep their charge under control, undercharging as well. This design uses a 30Amps charge controller in this circuit to ensure optimum battery and DC motor water pump performance.

(v) Cables

Different cables of different sizes were used to connect the components inside the system. Proper cable sizing was considered for every step depending on the current and voltage ratings of the devices and the operating temperature. 16mm^2 copper wires were chosen for the power circuit, joining the bus bars to the protective devices and switchgear to the capacitors. 4mm^2 was used for the control devices and 2.5mm^2 for the rest of the design.

(vi) Protective Devices

Every electrical construction project requires protection for its components and equipment. This is no exception. The primary reason for providing a protection device is to ensure safety for system components as well as end users.

(vii) AC/DC Converters

AC/DC converters are electrical circuits that convert the AC input into DC output. AC/DC converters are termed as "rectifiers"; they convert input AC voltage into variable DC voltage, which is then optimized through a filter to obtain unregulated DC voltage.

(viii) Arduino Microcontroller

The Arduino UNO is a simple microcontroller board based on the ATmega328P system. It has 14 digital input/output pins (of these, 6 can be used as Pulse Width Modulation outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

(ix) Float switch

A float switch is a device which perceives the liquid within a tank; it may actuate a pump, an indicator, an alarm, or other device connected to it.

(x) Liquid Crystal Display (LCD)

LCD is a flat panel display technology that finds application in televisions, computer monitors, smartphones, and digital watches. It works on modularly using liquid crystals to alter light to form images or text. There is a vast changing range for LCD applications-in the consumer and industrial domains.

(xi) Buzzer

Normally, a buzzer is a sound device that can convert electrical signals into sound. It is powered usually by a DC voltage. It is widely used in alarm systems, computers, printers, and many other products where sound is required.

3.6 Applications of Health, Safety and Environmental Standards to Design and Fabrication of DC/AC Level of water/Pump Control with Solar Power.

Safety is the responsibility of both the employer and the employee. They must work together to develop and implement safe working practices, procedures, and an electrical safety program. In this project's design and fabrication process, safety rules and regulations stipulated by the Occupational Safety and Health Administration (OSHA 29 Part 1910.333) and the National Fire Protection Association (NFPA 70E) were considered. The two regulations quoted cover the selection and use of electrical work practices. It defines and regulates such things as working on or near energised or de-energised parts. OSHA 29 Paragraph 1910.333 (a) (1) reads:

3.7 Detail Designs and Preparation of Detailed Drawings

These steps were taken during the design process:

(i) Figuring out the total load (Motor Horse-Power)

(ii) Selecting the desired power factor value

(iii) Computing the minimum and maximum power required based on solar panel power voltage outputs

(iv) Circle to diagram and drawings

(v) MCB or MCCB for their selection

(vi) Specific to the continuing turn of any of the new type of Arduino LCD and water sensor level to be complete

3.7.1 Determining Total Load

Total load is about figuring out the full load of the building or factory in this respect. For the design of whatever intended purpose, there is a process for the estimation of the total loading for the building or factory. In this paper, we chose to design for a 2-horsepower load. One horsepower is equal to 0.7457 kW.

3.7.2 Electrical Horsepower Conversion to Kilowatt

1 horsepower (hp) = 0.7457 kilowatts (kW)

1 hp = 745.7W = 0.7457 kW

So, the power conversion of horsepower to kilowatts is given by:

$$P_{(kW)} = 0.7457 \times P_{(hp)}$$

Therefore, using the water pump motor horsepower:

1 $hp_{(E)}$ = 745.7 W = 0.7457 kW

$P_{(kW)}$ =0.745.7 x $P_{(hp)}$

0.745.7 x 2 = 1.4914 kW.

Therefore, 2 horsepower is 1.4914 kW.

3.7.3 The Control System

The control system is shown in Figure 4. It consists of the LCD and some control circuits for the four 250-watt solar panels that serve as the source of the circuit.

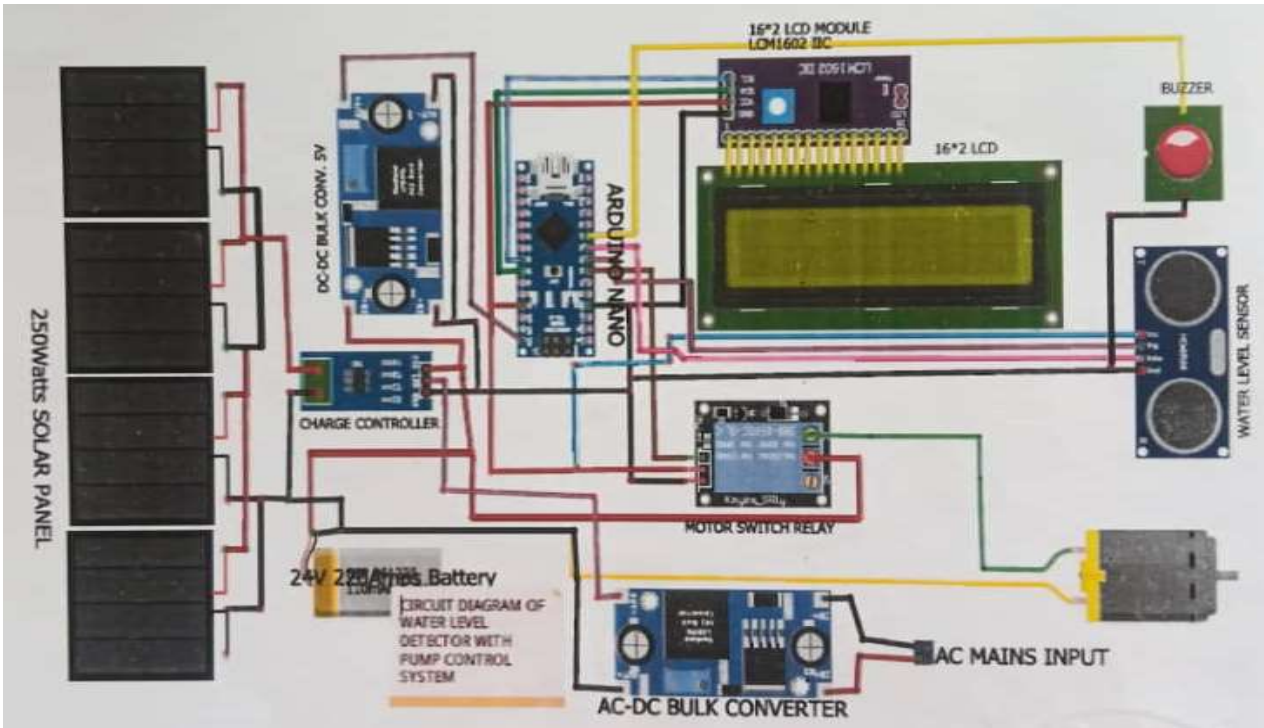

Figure 3: Circuit diagram of the control system

3.7.4 Control Board

The control board, also known as a control panel or control unit, is used in this electronic system to manage and regulate its operation. It typically consists of a circuit board with various electronic components such as microcontrollers, sensors, switches, relays, and displays. The control board receives input signals from sensors or user interfaces, processes these signals, and then outputs commands to actuators or other components to control the system's behaviour of this circuit.

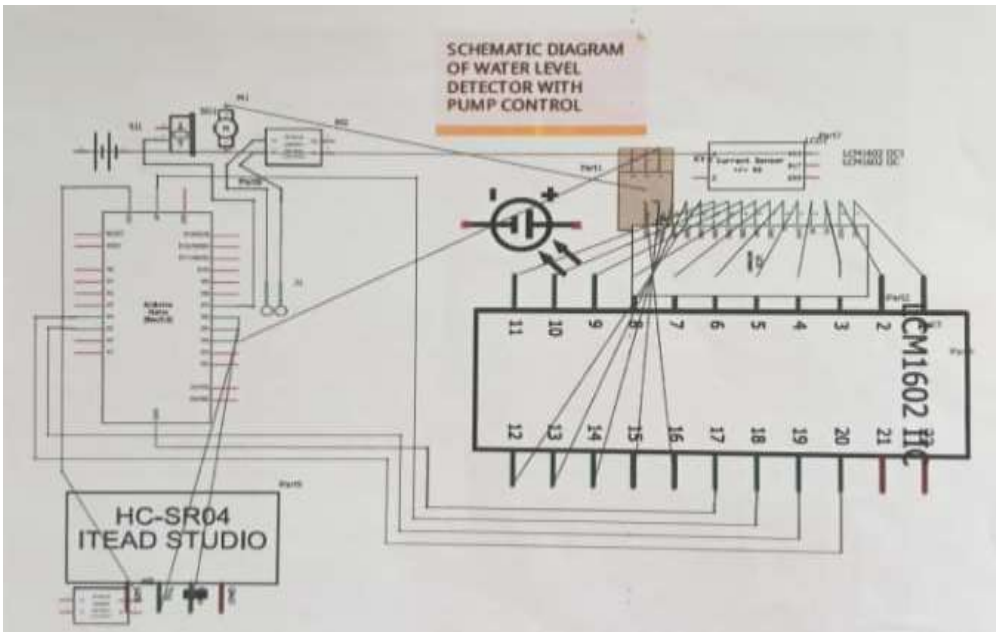

Figure 4: The schematic diagram of the control board

3.7.5 The Complete Control Board

The complete control system is shown in Figure 6. It consists of the entire system coupled together, as shown.

Figure 5: The Complete Control Board

4: RESULTS AND DISCUSSION

4.1 System Performance

The system was tested to determine its performance and accuracy. The results showed that the system was able to accurately monitor and control the level of water in the tank. The results also showed that the system was able to switch on or off the pump according to the level of water.

4.2 Cost Analysis

A cost analysis was conducted to determine the cost of the system. The cost analysis was based on the components used in the system. The results showed that the cost of the components was relatively low and the system could be implemented in rural areas.

Cost Analysis:

TABLE 1: BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

S/N	**Description of Items**	**Quantity**	**Unit Cost (N)**	**Amount (N)**
1	250 Watts Solar Panel	8	800,000	800,000
2	Solar Charge Controller	1	400,000	400,000
3	2 Horsepower DC Motor Pump	1	200,000	200,000
4	220 Amps Solar Battery	4	500,000	2,000,000
5	AC-DC Bulk Converter	1	40,000	40,000
6	Arduino Nano	1	120,000	120,000
7	16/2 LCD Module	1	15,000	15,000
8	12C LCD Interface Module	1	7,000	7,000
9	Single Channel Relay Module	1	8,000	8,000
10	DC-DC Bulk Converter	1	11,000	11,000
11	Buzzer	1	3,000	3,000
12	Ultrasonic Sensor	1	13,000	13,000
13	GP Tank	2	80,000	160,000
14	Tank Mount Pole	1	150,000	150,000
15	PCB Board	1	8,000	8,000
16	4 x 8 mm Cable	20 Yards	1200	24,000
17	Circuit Breaker	1	12,000	12,000
18	Logistics		70,000	70,000
19	Artistry		120,000	120,000
	Grand Total			**4,161,000.00**

4.3 Environmental Impact

The system is powered by solar energy, which is an abundant and renewable source of energy. This makes the system environmentally friendly solution for level of water monitoring in rural areas and reduces the impact on the environment.

Additionally, the system does not cause any noise pollution or air pollution, as it does not require any fuel or electricity to operate. The system is also designed to be low maintenance and can be easily installed and maintained in any area.

5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

This research paper describes the design and construction of a solar powered smart level of water monitoring system. The system was designed to monitor the level of water in a tank and to automatically switch on or off the pump according to the level of water. The system was tested to determine its performance and accuracy. The results showed that the system was able to accurately monitor and control the level of water in the tank. In addition, a cost analysis showed that the system was cost-effective and could be implemented in rural areas.

5.2 Recommendations

The following recommendations are proposed for further improvement of the system:

- The system should be tested in field conditions to determine its performance in realworld scenarios.
- The system should be tested for reliability and durability in order to ensure that it can withstand harsh environmental conditions.

- The system should be tested for compatibility with other systems and devices.
- The system should be tested for compatibility with various types of sensors and pumps.
- The system should be tested for safety and security to ensure that it is secure against malicious attacks.
- The system should be tested for scalability in order to ensure it can be easily expanded or modified.
- The system should be tested for energy efficiency in order to reduce energy consumption.

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