IoT Based Water Purification and Monitoring System Using Solar Energy

An Undergraduate CAPSTONE Project
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Faculty of Engineering

American International University - Bangladesh

IoT Based Water Purification and Monitoring System Using Solar Energy

A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

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DECLARATION

This is to certify that this project titled **"IoT Based Water Purification and Monitoring System Using Solar Energy"** is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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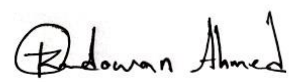

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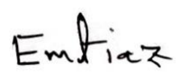

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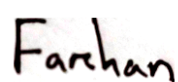

APPROVAL

The CAPSTONE Project titled **IoT Based Water Purification And Monitoring System Using Solar Energy** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in the respective programs mentioned below on **January 25, 2024** by the following students and has been accepted as satisfactory.

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We would also like to express our sincere gratitude to our parents who inspired us and classmates who helped us.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

An IoT-based solar-powered water purification and monitoring system is presented in this project work as integrated, autonomous, and efficient systems that can supply clean water. This research presents an approach to water purification by integrating Internet of Things (IoT) technology with solar energy to create a sustainable solution. The system comprises a water purification unit equipped with filtration and disinfection mechanisms, powered entirely by solar panels. The IoT framework enables real-time monitoring and control, ensuring optimal performance and user-friendly interaction. The solar energy subsystem harnesses sunlight through photovoltaic panels, storing excess energy in batteries for uninterrupted operation during low-light periods. A microcontroller is used as the system's central hub in this project. It communicates with various sensors, like as pH Sensor, Total Dissolved Solids (TDS) sensor, turbidity sensor, and temperature sensor. It measures water quality parameters and oversees the energy balance within the system. The collected data is transmitted to a Google sheet platform for storage and analysis. A user-friendly interface, accessible through a mobile app or web dashboard, allows users to monitor water quality metrics, system status, and energy levels. The system generates alerts for potential issues, providing users with timely notifications for maintenance or adjustments.

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Chapter 1

INTRODUCTION

The availability of hygienic drinking water in countryside zones turns into a main concern when pure water supplies are scarce or there are other environmental disasters. Due to the lengthy transport times for fresh water, the population of these places frequently suffers from health conditions. An Internet of Things-based water purification system using solar power is proposed in this project to generate fresh drinking water in areas where it is problematic to acquire pure water. This water purification system automatically fills purified water into a purifier using an automated valve. An onsite purification system stores the contaminated water after it has been collected. It might be possible to supply clean drinking water to those areas through this initiative.

1.1. Overture

There is no living thing that can survive without water. A living thing's body contains a great deal of water since it is vital to sustaining life. Despite its importance, water continues to suffer from pollution, especially during periods of industrialization. Polluted water greatly threatens life, especially because it causes deadly diseases. In this modern world, the scarcity of fresh water is decreasing daily. We need to use available technology efficiently. The strain we place on our resources due to the overuse of our planet's natural sources of energy is causing irreversible damage. In this project, we have envisioned a plant that can purify and produce fresh usable water from commonly available water that works on solar energy and is IoTbased. Direct photovoltaics (PV) indirect concentrated solar power, or a combination of both, is a method of converting sunlight into electricity. By utilizing the photovoltaic effect, photovoltaic cells convert light into electricity. Desalination is the process of purifying and filtering seawater through various methods (Electro Dialysis, Solar Still, Reverse Osmosis). An ion molecule and larger particles are removed from seawater using reverse osmosis through a semi-permeable membrane. Osmotic pressure is overcome by reverse osmosis by applying pressure, which is caused by chemical potential differences between solvents. By doing so, the pure solvent passes through the membrane, while the solute passes through the pressurized side.

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Microcontrollers and the concept of IoT are put into action to produce pure and clean water. Quality assurance is also made possible by the use of different sensing devices [1-2].

Bangladeshi seaside inhabitants deprived of access to grid electricity can now access clean drinking water through solar power through a convention worth nearly $5 million with Australia's F Cubed. A total of 1,140 solar powered water desalination units will be installed across 16 coastal districts by the Bangladeshi government. Approximately 30,000 people are expected to receive safe drinking water from the 500 W solar desalination systems – each driven by a 0.5 HP (373 W) water pump – as part of the Department of Public Health Engineering's Safe Water Supply Project Through Environment-Friendly Solar Desalination Unit program. More than 1,000 such systems are being procured for districts whose tenders are being issued. About 40 such systems have already been installed. The units supplied by F Cubed will be installed and maintained for three years by companies that are successful in installing and maintaining the systems [3].

Water treatment systems involve abstracting water from great (often distant) water sources for example rivers, lakes, or groundwater and treating it at a dominant location, tracked by distribution to customers through devoted dispersal systems in urban areas in Figure 1.1. Typical treatment capacities are average to great, helping the desires of towns and cities, and these processes usually include clotting, flocculation, sedimentation, purification, and fumigation [4].

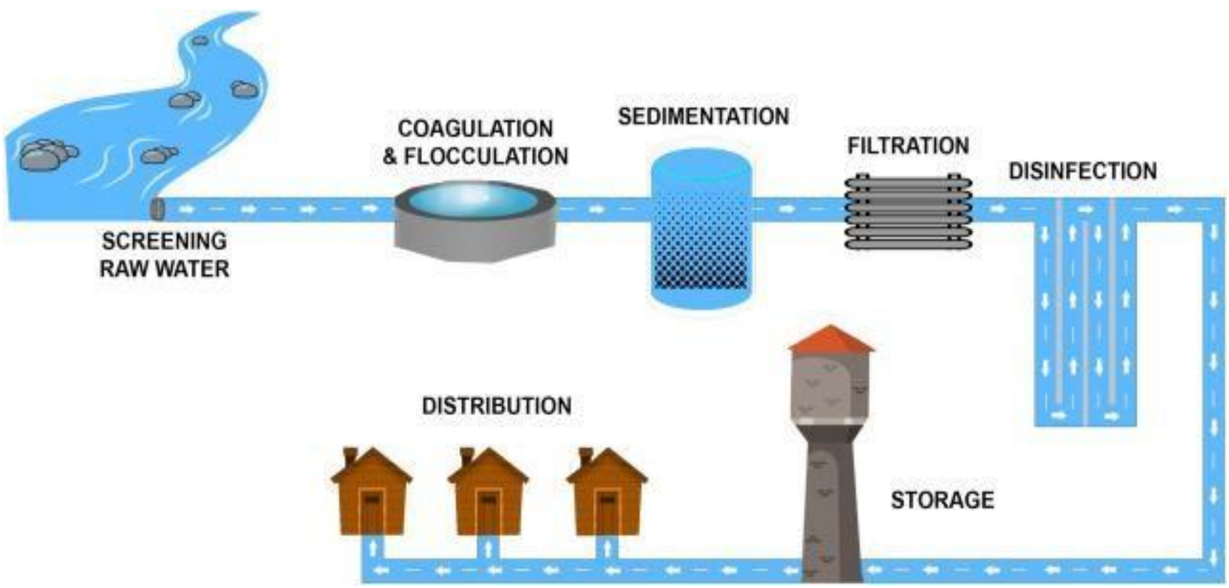

Figure 1.1: An overview of the water purification process

1.1.1. Bangladesh's Water Management Overview

Industrial effluents, domestic waste, and agricultural runoff are among the most common sources of contamination for surface water. Approximately 30 million people in rural areas are affected by

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arsenic contamination in groundwater used for drinking. Around 8.5% of all deaths in Bangladesh result from water and sanitation problems. Because of in in-height aquatic concept from global rivers by India besides environmental alteration, the salinity level in the soil and water has increased [5]. Within the next few hundred years, the massive mainstream of Bangladesh could be underwater because of sea-level escalation, according to the Global Climate Risk Index. The foremost water problems in Bangladesh are demonstrated in ***Figure 1.2***, which displays that flood, weather alteration, water adulteration, water distribution, and transparency dominate Bangladesh's water research and development [6].

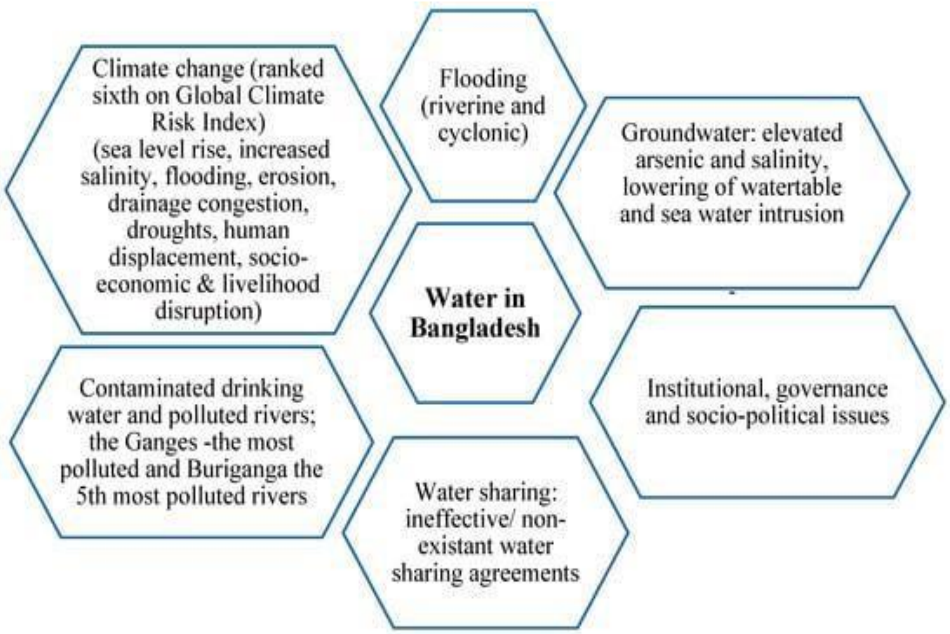

Figure 1.2: Bangladesh's major water issues illustrated

1.1.2. Hydrologic Cycle

It has been a centuries-old practice to distill water to make potable water. "The Hydrologic Cycle", a natural process of distillation, occurs when water on the earth's surface evaporates because of the sun's heat. Steam is also a form of evaporated water that is uncontaminated and clean. Clouds vaporize water, and it falls back to Earth in liquid form as rain when atmospheric temperatures fall. In areas where clean and safe drinking water is difficult to obtain, such as flood-prone areas, this same principle can be applied to generate clean and safe drinking water [7].

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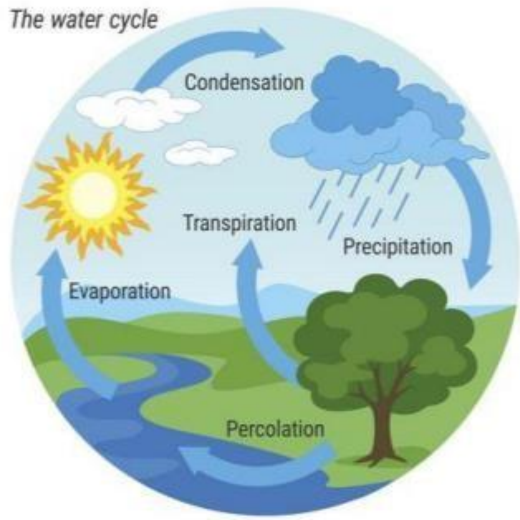

Figure 1.3: Hydrologic cycle

1.1.3. Solar Water Purification System

A solar dish cooker (SDC) is combined with a solar water heater (SWH) to produce highly productive and high-quality distilled water. Solar stills require a considerable amount of space to produce distilled water. A sequestered cupboard filled with saline/brackish water is enclosed in a transparent glass cover (glazing) that is simple to design and construct. The water is heated so that it evaporates besides then abbreviates on the inside of the translucent varnishing at a static slant angle in Figure 1.4 [8]. It is usually potable water that is transformed into distilled water, but the purity of this concentrate is also high since entire the scum is left behindhand during the entanglement process. During the summer, solar radiation raises the water's temperature sufficiently to kill all bacteria. The bottom of the cabinet is expected to cultivate a thin layer of slush, which can later be flushed as needed. Both ambient parameters and design parameters play an important role in determining the productivity and efficiency of a solar still, such as solar irradiance, ambient temperature, basin depth, glazing material, cabinet thickness, orientation of the system, insulation form, leakage, wind velocity, thermal heat storage (if any), also heat capacity [9].

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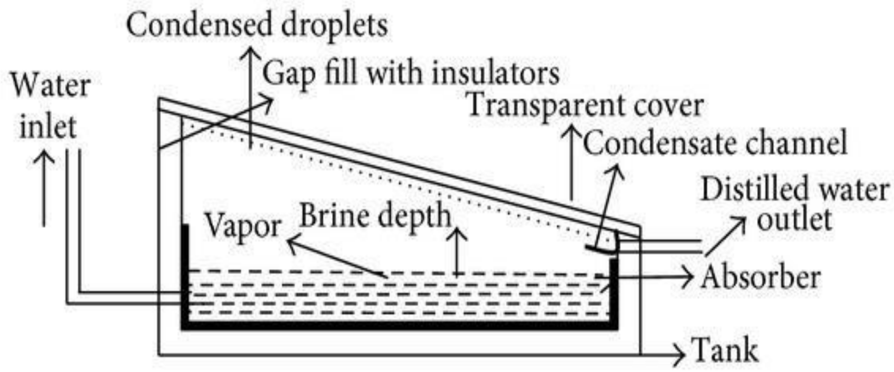

Figure 1.4: Solar still with a single slope, schematic diagram

1.2. Engineering Problem Statement

Waterborne diseases cause deaths and sickness in many rural communities because purified water is not available. Our goal is to develop a water purifier based on renewable energy and an IoT-based water purification and power monitoring device. A TDS sensor is used in place of a RO Purifier kit. For water filtering, we will assemble different sensors. Solar power is accustomed to power this system. Using a 20W solar panel, this system generates electricity. Backup power is provided by a 12V-7Ah battery. For nighttime or cloudy weather, backup power is secondhand. Because the system will be far away from us, going there every day won't allow us to see the device. To display the status of the device, we will add an IoT-based monitoring system. For example, the pH level of water, solar power, battery charge, and power consumption of devices. With a pH level sensor, we continuously measure the pH of the water. The pH level can be remotely controlled with IoT if it falls or exceeds the required level. Voltage and current sensors are used to monitor power consumption. The amount of power the solar system produces can be determined using current and voltage data. The power needed for running the system can be determined by measuring it. Our next step will be to measure how much charge the battery has. Since Blynk Server (third-party web server) is a fast server for control and monitoring, we will be able to monitor and control data in real-time. For future research, this server uses graphs. There is an Arduino controller used in this system.

1.3. Related Research Works

We found some research articles that match our work. Which are presented:

1.3.1. Earlier Research

A variety of related but distinct chemical processes known as "advanced oxidation" are used to combat soil, water, and air pollution. In the last few decades, a wide range of subjects have been

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studied through interdisciplinary research, including process basics, kinetics and mechanism clarification, material development, modeling, process integration, and scale-up. This article lists and examines many approaches that appear to progress research and development for advanced oxidation in water and wastewater treatment [9]. The design of a smart sensor interface for Internet of Things water quality monitoring is suggested. IoT offers a remote monitoring and operation interface that can be used from any location at any time. This suggested system makes use of an ATmega (ATMEL 328p) controller. When the suggested system's performance is evaluated for monitoring the water environment, better outcomes are obtained [10]. The primary goal of this project is to investigate the effects of contaminants including acid rain, saltwater, and waste lubricating oil on the prior concrete pavement. The findings demonstrate that in the acid rain, saltwater, or waste motor oil test, the pervious concrete pavement's pollutant and water purification both greatly improved. After the prior concrete pavement system, a diluted sulfuric acid solution (pH value 2.0) might greatly raise its pH value to 6.5 and higher. This study proves that using pervious concrete pavement is beneficial when designing roads and taking hydrologic factors into account [11]. Two traditional stills were used in this study; they had the same geometry, but the inside surfaces of their walls were painted white. At the Malawi Polytechnic, these solar stills were tested outdoors under the same weather circumstances (15° 42' S, 35° 02' E). During testing, the amount of distillate produced was measured. It was discovered that the experimental still and CSS produced 2.55 kgm-2 and 2.38 kgm-2 of distillate on average per day, respectively. Furthermore, the experimental solar still's efficiency was 6.8% higher than the CSS's. Thus, it may be said that painting the still's interior wall surfaces white enhances the still's ability to produce distillate [12]. The new system employs density difference flow principles to pasteurize water passively using solar power. A density difference between two columns of water regulates the flow of water in this system, which does not contain any valves. Previous designs caused boiling problems, which are no longer a problem with the new design. The treatment water should not be boiled since it may become contaminated. An absorbent area of 0.45 m2 has resulted in a peak flow rate of 19.3 kg/h. A density-driven system is an appealing option to existing solar water pasteurization approaches, as shown in experiments conducted on the prototype systems presented in this paper [13].

1.3.2. Recent Research

We go review the latest advancements in membrane materials, process setup, energy recovery devices, and energy storage in photovoltaic powered reverse osmosis (PV-RO) and solar thermal powered reverse osmosis (ST-RO). Furthermore, the last two years' developments in novel materials

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for sun-powered membrane distillation (MD) and solar stills have also been examined. The projection for the future takes into account the utilization of solar-powered forward osmosis and evaporation technologies in addition to hybrid renewable energy systems. Analysis of solar-powered desalination systems has focused on factors related to technology and energy usage [14]. This study aims to analyze the desalination systems that have been on the market recently, their energy, cost, and technology, as well as how well they interact with renewable energy sources. According to this review, the most feasible renewable desalination method for use in isolated arid regions is the solar still distillation (SD) system, which is essentially a natural evaporation-condensation process. More research is needed, though, in order to improve these systems' productivity and performance [15-16]. In this report, we provide an overview of our latest developments in material selection, molecular engineering, and structural design for hydrogel-based evaporators used in solar water purification. Firstly, we present the distinct water state seen in hydrogels, which comprises three types of water: free, intermediate, and bound. Among them, intermediate water exhibits a lower energy need for evaporating water. Next, we go over the design ideas for hydrogel-based solar evaporators, which use polymeric networks that are specifically made to control the water's condition. The way that water vaporizes in hydrogels is determined by its water state. As a result, the evaporation enthalpy of water may be further decreased by tuning the water state through the architecture of the hydrogels' polymer networks. Equipped with basic chemistry of gelation, we talk about hydrogel synthesis techniques for effective vapor production. Solar energy can be harvested and converted to heat energy by combining solar absorbers with hydrophilic polymer networks. This heat energy can then be used in situ to drive the vaporization of contained water in molecular meshes. Additionally, the solar absorbers' strong interactions with hydrogels direct the formation of microstructures to minimize energy loss and guarantee adequate water transport for evaporative water [17]. They see a portable, sustainable gadget that can be used in harsh environments and far-off places. It is a more ecologically friendly and cleaner technology since solar panels are used. Reverse osmosis candle filters, which employ reverse osmosis filters, are sold on the market for the purpose of filtering water. Pathogens and other microorganisms are desalinated, detoxified, and destroyed with it. The pH and turbidity of cleansed water are monitored and relayed to the user using IoT-based sensors. This kind of technology is essential for military operations in emergency situations, such a shipwreck or an attack, as well as in isolated areas without access to fresh water. If necessary, this portable module can be further altered to include a trash collector unit [18]. By putting together a water filtration system powered by renewable energy, this effort addresses the

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aforementioned issue. Reverse osmosis, or RO, is the purification system's foundation. The primary energy source for the purifying system is solar electricity. Charge controllers keep the battery running to prevent overcharging and maintain continuous power for the system. A Buck-boost converter provides an interface between the battery and the purifying unit. The purification unit consists of a water storage tank, an air mass motor, and a reverse osmosis (RO) system. The reverse diffusion is held by the air mass pressure. In order to keep the storage tank from overflowing, the Microcontroller 8051 monitors the pH and water level in the tank [19]. Statistical analysis was done on data gathered from five distinct water stations in Najaf for this study [20]. An interactive website that explains the water-purification process has been created specifically for users to showcase how the suggested system would be implemented. The water's pH level, temperature, nitrate, chloride, and dissolved oxygen concentrations, turbidity, oxidation-reduction potential (ORP), conductivity or total dissolved solids (TDS), and salt content may all be monitored remotely and intelligently using this system. The study's conclusions show that Najaf's drinking water quality is low and that the existing water purification system is not up to par with established water quality requirements. Findings from five locations show that observed water-quality parameter values are much lower than WHO recommendations. The suggested water-quality monitoring system greatly improves the quality of drinking water [20].

1.4. Critical Engineering Specialist Knowledge

A probable resolution to the world's problem of water purification may be to utilize alternative energy. During this project, innovative IoT-based, mainly water purification technologies have been developed and tested, which are evaluated comprehensively. Water purification systems based on solar power and the Internet of Things are recent developments and applications of these technologies. IoT technologies and chemical action processes are discussed in terms of their development potential. An analysis of efficiency, energy ingesting, and water manufacture charges of numerous skills is conducted by analyzing the performance knowledge obtained from recent studies. Water purification processes that use solar energy are underrated and have limited applications in the real world at present. A web server called Blynk was used for this project, as well as the Arduino Mega, a device that is operated in C++/C.

1.5. Stakeholders

A stakeholder is any person who knows the system, such as a regulator, employee of the local government, business representative, landowner, farmer, or other; they may also be a member of the scientific community. In addition to the solar-powered purification system, there is a Reverse Osmosis system that

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purifies water. Providing clean drinking water to rural areas is one of its main purposes. A good battery stores solar energy and could be a free energy source by using solar energy as a connected energy supply. This energy, an inexpensive basis of power for purifying water, was then victimized. As a result of this stage, rural and urban areas can receive water once again. This process usually yields a pure drink. In most cases, we follow a phase-by-phase approach to development, beginning with gathering client needs and ending with finalizing the plan. The analysis was conducted simultaneously with the device's production perspective. By applying a metaheuristic approach to the heating, cooling, and purifying processes, we typically optimize the basic procedure. This product will put an end to the shortage of clean drinking water when used properly. This purification procedure becomes conventional thanks to the pH measurement apparatus.

1.6. Objectives

We would be working on the implementation of an IoT based water purification system along with clean water support, our work has two phases of objectives.

1.6.1. Primary Objectives

- Purification of impurities from rural water is the vision of this project.
- Developing a system to purify water at a low cost.
- Water will be purified using renewable energy.

1.6.2. Secondary Objectives

- Monitoring the drinkable water purification system and to determine the state of the filters.
- To provide the real time information about the purification system to the user.
- The purified water quality parameters will be presented in the database.

1.7. Book Chapters Organization

Below is a synopsis of the forthcoming chapters along with a quick synopsis and title:

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Chapter 2: Project Management

The analyses of SWOT, PEST, cost, and schedule management have all been covered in this chapter. This chapter also covers the project lifecycle, multidisciplinary component management, and individual accountability. PEST analysis represents the project's external variables, and SWOT analysis represents its internal factors. Cost analysis, on the other hand, shows how the final expenditure and the predicted cost compare. This chapter covers project management and an overview of all the required components.

Chapter 3: Methodology and Modeling

When the key elements are nearly flawless, an accomplishment is deemed close. The goal of this chapter was to improve the water quality to the closest possible state of perfection. This chapter's main focal elements are the gap framework technique, flowchart, and block diagram. This chapter's goal is to present the project's methodology and guiding concepts. By analyzing the flow chart and system block diagram, we have demonstrated it. This chapter also covers the study of the flow chart and block diagram.

Chapter 4: Implementation of Project

The equipment used for the project and how it was done are the main topics of this chapter. These microcontrollers were employed in this project. Every component is seen above, complete with pictures and model specifications. This chapter includes a prototype approach for completing the major and secondary project goals.

Chapter-5: Results Analysis & Critical Design Review

After this project's results were examined, the analysis produced a very positive consequence. The expected outcome was successful. The simulation ran successfully. Not much was changed in the hardware to get the expected outcomes. The hardware's outcome and the simulation's result were comparable.

Chapter-6: Conclusion

The last chapter of this thesis book contains all of the author's closing thoughts, an analysis of the environmental impact, a list of the project's shortcomings, and recommendations for improvement.

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Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

A project management approach is one of the most common methods used to ensure a project's success. Managing projects requires defining the objectives of the project, determining what resources will be needed, and accomplishing them. This chapter focuses on getting things done. In project management, the stated goals and deliverables of a project are planned, executed, and achieved as specified. In addition, identifying and controlling potential risks, as well as communicating across organizations, are part of this process. Using a Gantt chart can help with project scheduling. Saving money on the project's equipment is possible by altering the data. One essential managerial skill is project management. To complete the process within a certain budget and time limit, actions must be planned, scheduled, and regulated. Businesses can meet their objectives when they complete initiatives that contribute to project aims. An important characteristic of most projects is a precise start and end date, a precise number of contestants, a precise budget, and an exact number of resources. In this case, the group leader plans and monitors the process and makes adjustments as needed. Skill has made life laid-back. Researchers are developing new devices every day. IoT monitoring systems and solar-powered water filtration can be advantageous for our nation. For those who live in isolated places, this is a blessing because there won't be any electricity.

2.2. Analysis of S.W.O.T.

The SWOT outline can be used to analyze a project's opportunities, threats, strengths, and weaknesses. In the internal analysis of the projects, the functional approach pinpoints their strengths and weaknesses (finance, management, organization, procurement, manufacture, dispersal, marketing, reputational factors, besides revolution), along with their opportunities for growth and weaknesses (the same). An in-depth study of the internal factors that contribute to competitive advantage is required. By identifying motivational areas, it identifies where resources should be developed to keep teams engaged. An analysis of the external environment, including competitors, industries, and broader economic conditions, reveals potential advantages and disadvantages in a sector. The competitive landscape is formed by analyzing the assets and capabilities of each competitor. Using the five forces model, we analyze the industry's external environment, including competition, new participants, suppliers, customers, and merchandise replacement. The exterior

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atmosphere is considered in terms of political, economic, sociological, technological, environmental, demographic, principled, and monitoring repercussions. An organization's Strategy Development process will be informed by a SWOT analysis of its Strengths, Weaknesses, Opportunities, and Threats (SWOT). SWOT analysis is used to identify strengths and weaknesses.

2.2.1. Strengths

Benefits of the project:

- It was anticipated that this project would have a look. There is a possibility that this project will be used around the world in the future.
- Our project will cost a reasonable amount.

2.2.2. Weaknesses

Weaknesses of the project:

- The prototype runs in the solar system so, bad weather may cause unsuccessful action.
- The system will have an internet connection for monitoring at all times.

2.2.3. Opportunities

The potential for gaining a competitive advantage comes from factors outside of your control. There is no doubt that water-borne illnesses are responsible for many deaths every year. The cost of treating it is high. The majority of people are unable to afford this. The installation of deep tube wells for pure water is not feasible in many places. Its purpose is to safeguard people from waterborne illnesses and ensure they have access to clean water.

2.2.4. Threats

The use of green energy here does not pose any environmental risks. Because it will be used in rural areas and frequent maintenance visits will be necessary, it could cause damage to the system if it is not operated properly.

2.3. Management of Schedules

Project activities are arranged using time variables as part of a scheduled management structure. Outlines the steps that must be taken to ensure that the project is completed on schedule and within the allocated budget. To manage a project effectively, track its progress, and ensure its completion on schedule, the

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implementation of a schedule management system is crucial. Additionally, by ensuring that resources are used effectively and efficiently, good schedule management may assist to save costs and enhance resource utilization. Project managers may contribute to making sure that projects are finished effectively and on time by carefully creating and monitoring the schedule. Figure 2.1 below displays the Gantt chart that we used to manage the project's schedule:

Figure 2.1: Gannt chart

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2.4. Analysis of Cost

Table 2.1 shows the overall cost analysis of authentication and water purification devices. Here, the component's price are displayed.

Table 2.1: Cost of components

Components Name	**Price (Taka)**
Arduino Mega	2200
TDS Sensor	2185
WIFI Module	325
Turbidity sensor	1545
pH Sensor	3140
DS18B20	180
Solar Panel 20 Watt	1600
Solar Charge Controller	570
I2C LCD Display	550
LM2596	125
Power Supply	420
Battery	1500
Voltage Sensor	99
Current sensor	180
Others	400
Total cost	**14659/-**

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2.5. Analysis of P.E.S.T.

When assessing a project's existing circumstances, upcoming possibilities, and tactical design of achievement, the PEST examination is a crucial part. A PESTLE analysis also deliberates other features, for instance, those associated with the environment also legislation. PEST analysis consists of four main points:

2.5.1. Political Analysis

By making political structures, institutions, ideas, and behaviors accessible and engaging, political analysis is enhanced. Of particular importance are the political processes that shape and change these structures and behaviors throughout time. This project won't require government clearance in order to execute its plan. This project has no restrictions on how it may be completed. This concept has a great deal of potential if politicians in charge of transportation agree to integrate this system into their operations.

2.5.2. Economic Analysis

Cost-benefit analysis is the cornerstone of economic analysis. First, it assigns a project's economic feasibility a rating in order to allocate money more efficiently. The aim of this study is to evaluate the social impact of a project.

2.5.3. Social Analysis

In social analysis, as many relevant stakeholders as feasible are included in the development process and their objectives and views are analyzed. We do this research taking into account the historical, political, institutional, sociocultural, and financial background of bank-financed operations. This is a group project, and certain cultural behaviors, trends, or attitudes may have an influence on the audience it is meant for. Considering that the initiative aims to help society's citizens, this problem cannot be disregarded. Without the ability to benefit society, this endeavor cannot benefit society. Since society's citizens face many problems, the project's possibilities are also affected by them. We really hope that this project will help our community. After filtration, fish farming may be done using the leftover wastewater. This water is perfect for fish aquaculture because of its high TDS content.

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2.5.4. Technological Analysis

A primary objective is to achieve the greatest feasible cost-effectiveness for this project. Technically speaking, the project should use readily available, low-cost technology, and building a system shouldn't call for expensive gear. The goal was to construct this system using the technology that was already available.

2.6. Professional Responsibilities

Ensuring the efficacy and safety of a system, process, or product is the duty of an engineer. To ensure the success of a project, engineers need to be good team players and collaborators. Engineers and clients must communicate effectively.

2.6.1. Norms of Engineering Practice

A "norm" refers to a system of moral rules or principles. Normative design should be used to balance technological and ethical possibilities when making trade-offs in design. Engineers are mandated by law to do impact assessments in order to guarantee that designs have a good effect on society. Ensuring that your staff members feel appreciated is essential for business owners. If engineering managers want to accomplish their jobs efficiently, they have to give staff talent development a high priority. The manager has to have a clear plan for the staff's progress and keep the lines of communication open on each employee's abilities, requirements, potential, and objectives.

2.6.2. Individual Responsibilities and Function as Effective Team Member

For a group effort to be successful in the end, collaboration is essential. It's critical to have effective communication with your teammates. Another crucial factor is leadership quality. There will be excellent results when everyone does their part.

Redowan Ahmed: Completed chapters 5, 6, and 7 of this thesis book. Also, a research analysis of the thesis book has been completed. The hardware and the entire simulation component are finished.

Md Emtiaz Ahamed: assisted with setting up the hardware and wrote chapters 2 and 4 of this thesis book.

Md Farhanul Islam: Involved in drafting chapters 1 and 3 of this thesis book. The project's research analysis and component gathering from various locations has been completed effectively.

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2.7. The Principles of Management and Economic Models

Economists use models to simplify their explanations of reality and generate testable theories about how the economy behaves. The intrinsic subjectivity of economic models stems from the absence of a commonly accepted metric for assessing economic performance. Diverse economists will reach differing assumptions about what is needed to account for the biosphere as they understand it. Theoretical and empirical are the two main categories of economic models. Theoretical models work below the assumption that negotiators exploit given purposes inside distinct model limitations to infer observable implications regarding economic behavior. They offer thorough assessments of intricate problems, like market imperfections and the results of asymmetric knowledge—the situation in which one side of a transaction possesses more information than the other. Conversely, empirical models seek to translate the qualitative findings of theoretical models into more tangible numerical outcomes. For example, if we applied a 22-theoretic model of consumer behavior, we may expect that spending would increase in tandem with income. The theoretical model would be empirically updated in an attempt to attempt to assign a monetary value to the normal percentage rise in spending that happens with a percentage increase in income. Moreover, research area units are classified according to relevance objectives, approaches, locations, and key findings. Based on the literature, IoTbased solar-based water purification technology has once again emerged as an economically viable and technologically feasible option. For researchers interested in analyzing IoT-based solar energy water purification systems from a modeling and techno-economic optimization standpoint, this review is particularly useful.

2.8. Summary

The analyses of SWOT, PEST, cost, and schedule management have all been covered in this chapter. This chapter also covers the project lifecycle, multidisciplinary component management, and individual accountability. PEST analysis represents the project's external variables, and SWOT analysis represents its internal factors. Cost analysis, on the other hand, shows how the final expenditure and the predicted cost compare. This chapter covers project management and an overview of all the required components.

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Chapter 3

METHODOLOGY AND MODELING

3.1. Introduction

According to World Health Organization (WHO) projections, over 50% of the global population is expected to live in areas with limited access to water by 2025. A sustainable and profitable alternative to conventional water purification may provide access to potable water that is clean and secure. Almost all alternative energy-driven chemical process systems include water evaporation as a principal process. The improved thermo-physical properties and optical tunability of nanoparticles propose a significant boost in evaporation rates and, thus, a clean water supply may result from the addition of nanoparticles to water [21]. For the past few decades, solar electricity has been used for heating. Homes and commercial buildings are typically supplied with hot water through it. Photosynthesis is the process of renovating solar energy into electricity using solar cells. Solar cells of this type are made of high-purity metallurgical silicon that's been chemically purified [22].

3.2. Block Diagram and Working Principle

3.2.1. Block Diagram

Figure 3.1: The block diagram of the system

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In this Block Diagram in Figure 3.1, we are using solar panels, Charge controllers, batteries, voltage regulators, temperature sensors, turbidity sensors, TDS sensors, pH Sensor, Arduino Mega, LCD 2004, and ESP8266. Here Arduino is the main microcontroller, pH Sensor, TDS, Turbidity and temperature sensors are the input of Arduino Mega and LCD 2004 and ESP8266 are the output from the Arduino Mega.

3.2.2. Flow Chart

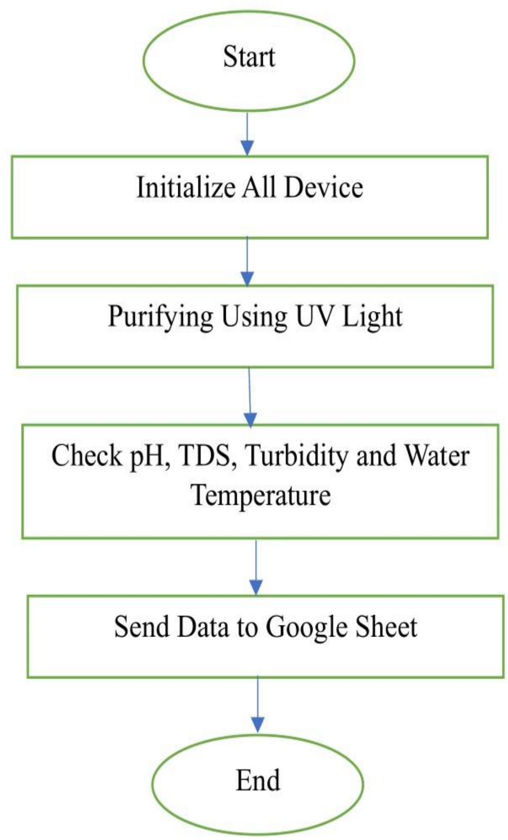

Figure 3.2: Flow chart

The UV light will turn on after the device has been powered on. After adding water to our water jar, we will move the water to another jar after 30 minutes. An Arduino microcontroller will receive data from a water flow sensor that measures the temperature, turbidity, pH, and TDS of the water. then turn on the display and use an IoT device to transfer the data to a Google Sheet.

3.2.3. Working Principle

IoT-Based Water Purification and Monitoring System Using Solar Energy. This project is completely solar powered, we have used 20-watt solar panels and a solar charge controller. 12-volt 7.5-amp

- lead acid battery. We use UV light to purify water. I have used 4 sensors to check the water quality. pH sensor to measure the acidity and alkalinity of water. TDS (Total dissolved solid) is an indicator of water cleanliness. How many milligrams of dissolved solids are dissolved in each liter of water is expressed as TDS (Total dissolved solid). The lower the TDS, the clearer the water. The unit of TDS is ppm. 1 ppm=1mg/Liter. By comparing the chart below, we can understand how pure our drinking water is by determining the TDS. Turbidity is a very important indicator in controlling water quality. How cloudy the water is can be understood by measuring turbidity. Another sensor is the waterproof temperature sensor. Through this you can understand the temperature of the water.

3.3. Summary

When the key elements are nearly flawless, an accomplishment is deemed close. The goal of this chapter was to improve the water quality to the closest possible state of perfection. This chapter's main focal elements are the gap framework technique, flowchart, and block diagram. This chapter's goal is to present the project's methodology and guiding concepts. By analyzing the flow chart and system block diagram, we have demonstrated it. This chapter also covers the study of the flow chart and block diagram.

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Chapter 4

PROJECT IMPLEMENTATION

4.1. Introduction

The objective of this project is to a solar-powered IoT-based water purification system, more specifically Arduino and Node MCU. Sensors including charge controllers, pH sensors, water flow sensors, voltage sensors, current sensors, etc., have been used in this study. This project uses a 20W solar cell for power generation. Batteries are charged by solar cells through solar charge controllers. Before project implementation, many components were purchased. They were then put together. Following the first assembly of the parts, a few issues needed to be resolved. The issues were resolved once a few transformers were changed. Subsequently, we built the programming and created the water purification system. These implementations were all carried out with consideration for engineering ethics and safety.

4.2. Required Tools and Components

Required hardware components are discussed below.

Arduino Mega

A standalone Arduino or an Arduino connected to a computer can be used to build interactive objects. Using the Arduino IDE (Integrated Development Environment) boards can be built by hand or sold assembled. This embedded system uses the Atmel microcontroller clan with standard hardware on a board that has an inherent boot loader for plug-and-play software design. Arduino Software includes an IDE for writing, debugging, and creating programs. Serial data can also be easily retrieved from the board using the Serial Communication window in the IDE.

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Figure 4.1: Arduino Mega

A Mega board is an ATmega2560-based microcontroller. A USB connector, a power jack, an ICSP header, plus a reset button are present, along with 54 input/output pins (16 of which tin be cast off as PWM productivities). Pin Mode (), digital Write (), and digital Read () allow each of the 54 digital pins to function as an output or as an input. The pins run on five volts. As noted in the working conditions, the pins have an extreme current rating of 20mA and a default inner pull-up resistor (cutoff) of 20-50k ohm. The maximum current that can be applied to whichever I/O pin is 40mA to prevent irreparable damage to the microcontroller.

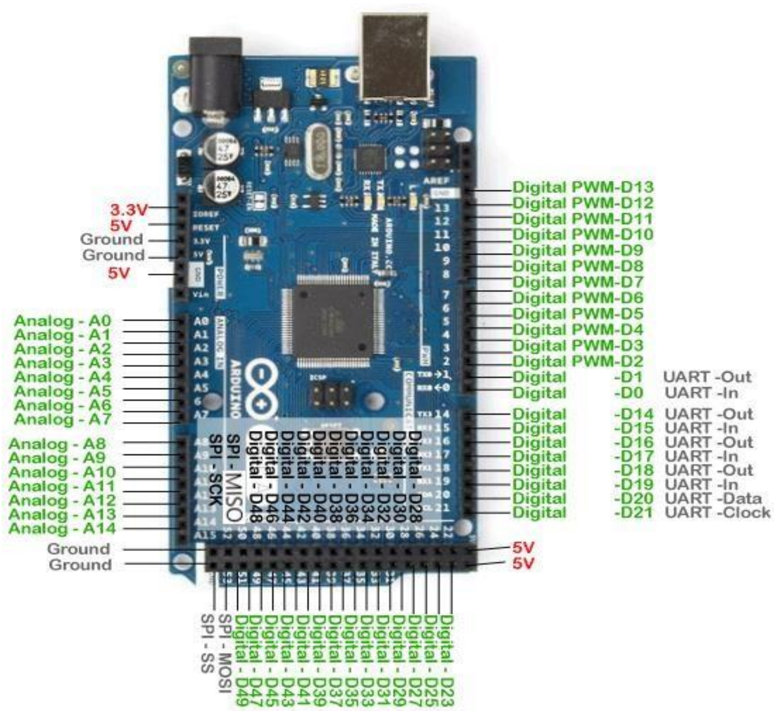

Figure 4.2: Pin Description of the Arduino Mega

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Pin Specification

- 0 (RX) and 1 (TX) for getting also transferring serial data.
- 2 and 3. A stumpy rate, a growing or dropping verge, or a variation in value can trigger an interject.
- 3, 5, 6, 9, 10, and 11. The analog Write () function delivers 8-bit PWM output.
- 10(SS), 11(MOSI), 12(MISO), 13(SCK). The SPI library supports these pins for SPI communication.
- Digital pin 13 controls the built-in LED.
- Supports TWI communication with A4 or SDA and A5 or SCL pins.

ESP8266

Espressif Systems produces the ESP8266 a stumpy-rate Wi-Fi chip with GPIO and TCP/IP networking proficiency incorporated into a microcontroller, and it is available for purchase in Shanghai, China. English speaking makers were first introduced to the chip through Ai-Thinkers' ESP-01 module. The ESP8266 is a liberated Wi-Fi arranged controller proposing an allowance to the present small-scale regulator via Wi-Fi, as well as being able to run independent software programs. It has an incorporated USB port and a variety of twig outs. Using a lesser USB link, we can easily attach Node MCU to a PC and use it the same way as Arduino. It is also immediately inviting with its breadboard.

Figure 4.3: ESP-8266

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Description:

- Voltage: 3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Current ingestion: 10uA~170mA.
- Flashy memory removable: 16MB max (512K normal).
- Incorporated TCP/IP decorum pile.
- Processor: Ten silicaL106 32-bit.
- Processor speediness: 80~160MHz.
- RAM: 32K + 80K.
- GPIOs: 17 (multiplexed by extra tasks).
- Analog to Digital: 1 input with 1024-step determination.
- +19.5dBm output power in 802.11b mode
- 802.11 support: b/g/n.
- Extreme synchronized TCP associates: 5.

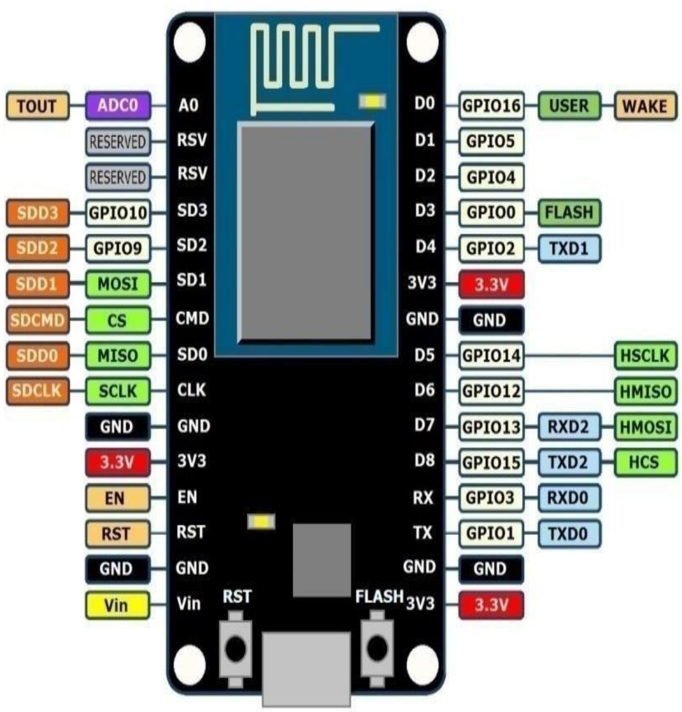

Figure 4.4: ESP8266 Node MCU

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Table 4.1: ESP8266 Node MCU Pin Specification

Pin Number	**Pin Name**	**Alternate Name**	**Usually used for**	**Alternate persistence**
1	Ground	-	Grounded to the circuit	-
2	TX	GPIO – 1	Linked to Rx pin of programmer/uC to upload program	The pin can be used for general input/output when not operating as a TX
3	GPIO -2	-	General purpose Input/output pin	-
4	CH_EN	-	Chip Enable– Active high	-
5	GPIO - 0	Flash	General purpose Input/output pin	During startup, hold low to enter serial programming
6	Reset	-	Resets the module	-
7	RX	GPIO - 3	General purpose Input/output pin	Can act as a Generalpurpose Input/output pin when not used as RX
8	Vcc	-	Connect to +3.3V only	

20W Solar Panel

Through the photovoltaic effect, light energy (photons) is transformed into electricity in photovoltaic modules. The majority of modules employ thin-film or crystalline silicon wafer-based cells. A load-bearing structural element may be located at the front or back of a module. Moisture and mechanical degradation should be the two main threats to membranes. Semi-flexible modules based on thin-film cells are also available. The cells are linked in series to produce voltage, and the equivalent is an increase in current. The

-

voltage and current of the module are multiplied to get the module wattage. It is not always the case that solar panel manufacturers base their specs on the actual conditions at the installation location. The output interface of solar panels is a PV junction box located at the rear of the panel. The majority of photovoltaic modules are linked to the rest of the system using MC4 connections to guard against weather damage. Additionally, USB power interfaces are included.

The PV system or solar panels are connected in series or parallel to provide the required output of voltage or current. Depending on their capacity, the conductors that remove the current from the modules might be made of silver, copper, or other non-magnetic conductive transition metals. When a module is partially shaded, bypass diodes can be added either internally or externally to increase the output of the areas that are lit. Mirrors or lenses in solar PV modules with concentrators direct sunlight onto smaller solar cells. It is an economical method of employing expensive per-unit cells (like gallium arsenide). In addition to the metal frame, the solar panel is supported better by troughs, reflector shapes, and brackets.

Figure 4.5: Solar panel

Features

- 12V off-grid solar panel.
- 0~+5W guaranteed positive power output.
- IP 65 or IP 67 rated.
- Built with an aluminum frame and sturdy tempered glass;
- Designed to survive harsh climatic conditions;

-
- Offers exceptional low-light performance on overcast days, early in the morning, and late at night.

Solar charge controller

The solar charge controller regulates the voltage and current coming from the solar panel to the battery to prevent overcharging. A 15-A/200-W unit is programmed to charge the battery up to 30% faster than a conventional unit that uses MPPT (maximum power point tracking).

Figure 4.6: Solar charge controller

Features

- Model: 10A
- Charge Current: 10A
- Discharge Current: 10A
- Battery Voltage: 12V/24V Auto
- Max Solar Input: <41V
- Equalization: 14.4V
- Float: 13.7V (default, adjustable)
- Discharge stop: 10.7V (default, adjustable)
- Discharge reconnect: 12.6V (default, adjustable)
- Standby current: <10mA

-
- USB output: 5V/2A Max
- Size/Weight: 133 x 70 x 35mm/132g

LCD 20*4

The LCD (liquid crystal display) module features four rows in the display, each showing twenty characters, with the entire display showing eighty characters. Using HDD44780 for its monochrome text display, the liquid crystal module uses parallel interfacing.

It is easy to access the code for interfacing liquid crystal displays. To interface the LCD screen, we need eleven input and output pinouts. Three volts or five volts is the input supply for this module, with other components like the PIC, Raspberry PI, and Arduino.

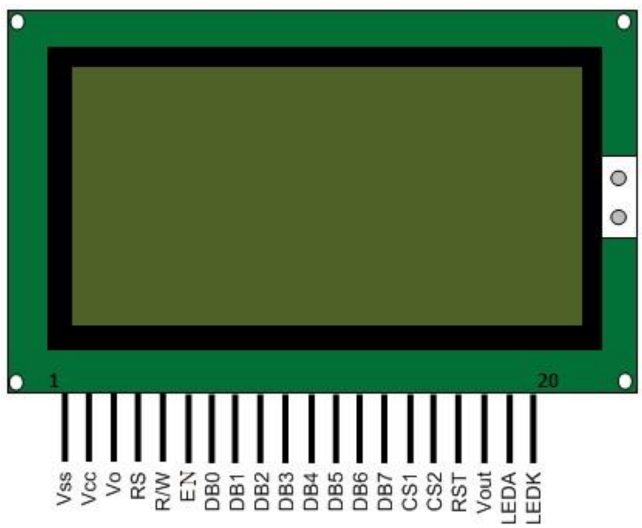

Figure 4.7: LCD 20*4

The LCD has four lines of 20 characters each, so it displays four characters per line. There are 5x7 pixels on each character. In addition to the command register, it also contains a data register.

This is a description of some of the characteristics of 20 x 4 LCD modules.

- Its most noteworthy feature is that it displays up to 80 characters at one time.
- This module has a cursor that measures 5 x 8 (40 pixels).
- The RW1063 controller is already integrated into this module.
- Input voltage is plus five volts, but it can also handle plus three volts.

-
- It is also possible to use the negative supply pinout on the three-volt pinout.
- This module runs on a one-to-16 cycle (1/16).
- In this module, the light-emitting diode can get power from pinout 1, pinout 2, pinout 15, pinout 16, or pinout A and K.

Table 4.2: LCD Pinout

Pin No	Pin Name	Factors
1	It is signified as Vss	This pinout has zero ground potential.
2	It is signified as Vdd	At this pinout, five volts are delivered.
3	This pinout signified as Vo	Screen contrast is set using this pinout.
4	This pin signified as RS	It is used to H/L register select signal.
5	It is signified as R/W	It is used for H/L read/write signal.
6	This pinout signified as E	It is used for H/L enable signal.
7-14	The pinouts from seven to fourteen are meant as DB0 – DB7.	It is used for H/L data bus for 4-bit or 8-bit mode.
15	It is recognized as A (LED+)	Set the backlight anode.
16	It is recognized as K (LED-).	Set the backlight cathode.

I2C

Using the I2C Driver, can control I2C devices over USB easily and quickly. It's compatible using Windows, Mac, and Linux plus has an integral color display with a living I2C activity dashboard.

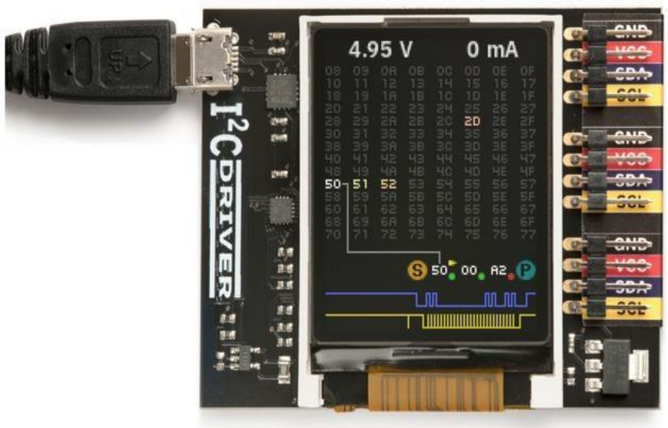

Figure 4.8: I2C driver

Stipulations

- Extreme power out current**:** up to 470 mA
- Expedient current: equal to 25 mA
- Measurements: 61 mm x 49 mm x 6 mm
- Computer edge: USB 2.0, micro USB connector.

pH Sensor

The pH scale ranges from 0 to 14 and measures the acidity or alkalinity of a solution. Certain solutions have a pH value indicating the concentration of hydrogen [H] + ions. A sensor that measures the potential difference between two electrodes can accurately quantify hydrogen ion concentration. The electrodes are both silver (silver chloride) and glass (sensitive to hydrogen ions). This is what forms the probe. This sensor can also be controlled using an electronic circuit, such as an Arduino microcontroller, to condition the signal appropriately [23].

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Figure 4.9: pH sensor

Specifications

- Supply Voltage: 5 V
- Current: 5-10 mA
- Consumption: ≤ 0.5 W
- Working temperature: 10-50 ºC

TDS sensor

Water quality can be determined using the Grove - TDS Sensor, which measures Total Dissolved Solids (TDS) in the water. Essentially, total dissolved solids (TDS) are calculated by summing all molecular, ionized, and micro-granular colloidal suspended substances as a measure of all inorganic and organic substances in a liquid measure of all dissolved materials in water that are not H2O molecules, and they include both organic and inorganic materials such as metals, minerals, salts, and ions. TDS is calculated by summing all molecular, ionized, and micro-granular colloidal suspended substances as a measure of all inorganic and organic substances in a liquid. Small solids must be able to pass through a sieve with a size of two micrometers without being destroyed [24].

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Figure 4.10: TDS sensor

Specification

- Input Voltage: *3.3 ~ 5.5V*
- Output Voltage: *0 ~ 2.3V*
- Working Current: *3 ~ 6mA*
- TDS Measurement Range: *0 ~ 1000ppm*
- TDS Measurement Accuracy: ± *10% FS (25 ℃)*
  TDS probe with Number of Needles: *2.*

<u>Water Flow Sensor</u>

A large amount of water is needed to supply industrial plants, commercial buildings, and residential structures. To meet this requirement, public water supply systems are used. Measurement of the flow rate of water is important for monitoring the amount of water supplied and used. This can be achieved by using water flow sensors. To calculate how much water flows through the pipe, water flow sensors are installed at a source or in pipes where water flows. Meters per hour or liters per cubic meter is the unit of measurement for water flow [25].

-

Figure 4.11: Water flow sensor

Features

- Sensor Type: Hall effect
- Working Voltage: 5 to 18V DC (min tested working voltage 4.5V)
- Max current draw: 15mA @ 5V
- Output Type: 5V TTL
- Working Flow Rate: 1 to 30 Liters/Minute
- Working Temperature range: -25 to +80℃
- Working Humidity Range: 35%-80% RH
- Accuracy: ±10%
- Maximum water pressure: 2.0 MPa
- Output duty cycle: 50% +-10%
  Output rise time: 0.04us
- Output fall time: 0.18us
- Flow rate pulse characteristics: Frequency (Hz) = 7.5 * Flow rate (L/min)
- Pulses per Liter: 450
- Durability: minimum 300,000 cycles
- Cable length: 15cm

-
- 1/2" nominal pipe connections, 0.78" outer diameter, 1/2" of thread
- Size: 2.5" x 1.4" x 1.4".

Turbidity Sensor

Turbidity is measured by Arduino's turbidity sensor to determine the quality of water. The light transmittance and scattering rate change when water contains total suspended solids (TSS), allowing the sensor to detect suspended particles in water. The liquid turbidity level rises as the TTS does. There are two ways to output signals from this Arduino turbidity sensor: analog and digital. With digital signal mode, you may choose the mode based on the MCU since the threshold can be adjusted. Turbidity sensors can be used for laboratory measurements, wastewater and effluent measurements, sediment transport studies, and river and stream water quality assessment [26].

Figure 4.12: Water turbidity sensor

Specifications

- Operating Voltage: 5V DC
- Operating Current: 40mA (MAX)
- Response Time: <500ms
- Insulation Resistance: 100M (Min)
- Output Method: Analog
- Analog output: 0-4.5V
- Digital Output: High/Low-level signal (you can adjust the threshold value by adjusting the potentiometer)
- Operating Temperature: 5℃~90 ℃
- Storage Temperature: -10℃~90℃
- Weight: 30g

Current Sensor

This device detects and converts electricity into a quantifiable output voltage proportional to the current moving over it. Every sensor is appropriate for a particular variety of current also ecological conditions, and each sensor is priced differently. Current sensing resistors are commonly used for these sensors. Through the use of a resistor, a voltage is linearly converted from a current. For different sensors to apply to various applications, the technology used in the current sensor must be relevant.

Current sensors are based on either open or closed-loop Hall-Effect technology. During a closed-loop sensor, a coil produces a magnetic field that opposes that of the current being measured. Null-detecting devices use the hall sensor, which outputs a signal proportional to the current that is driven through the coil, which is proportionate to the current being measured.

Using a hall device, open-loop current sensors measure the magnetic flux from the primary current, which is concentrated in a magnetic circuit. Hall devices are designed to output a signal that represents the primary current exactly (instantaneously).

Figure 4.13: Current Sensor.

Description

- The chip is ACS712ELC-30A.
- Pin 5V power source involved power light.
- The module can be dignified plus otherwise minus 30A current, with the equivalent analog output of 66 mV/A.
- No experiment current over the output voltage is VCC/2.
- PCB dimension: 31 (mm) × 13 (mm).

<u>AC Voltage Sensor</u>

For DIY projects requiring accurate AC voltage measurements, the ZMPT101B AC Voltage Sensor is the ideal choice. Arduino/ESP8266/Raspberry Pi is an ideal open-source platform for measuring AC voltage. Engineers often deal directly with measurements in electrical projects with limited elementary necessities such as galvanic segregation, inclusive range, high accuracy, and reliable constancy. The dynamic phase AC output voltage transformer module committed includes an exact miniature voltage transformer. A precision op-amp circuit, signals sampling, and the necessary reparation onboard ensure precise functions. Within 250V AC voltage, modules can be measured, and their analog outputs can be accustomed. The device is pristine, and it is of very high quality.

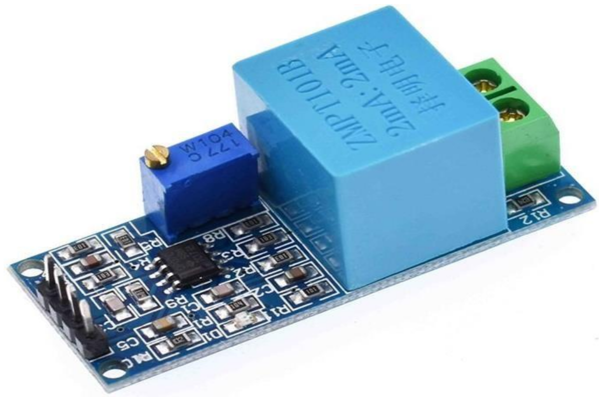


Figure 4.14AC Voltage Sensor Module ZMPT101B

Topographies

- Little price
- Lesser size and lightweight
- Simple PCB intensifying
- Good reliability
- Extensively commended.

DS18B20

An enhanced version of the DS18B20 temperature sensor, waterproofed. Measurements in wet or remote locations are made easier with this device. Even though the sensor is capable of 125°C, we recommend keeping the cable under 100°C due to its PVC jacket. Due to their digital nature, the signal doesn't degrade over long distances either! One wire (and ground) are needed to connect the DS18B20 to a central microprocessor, so only one wire (and ground) is required. The device operates between 3.0 and 5.5V. As each DS18B20 has its own unique silicon serial number, it can share a 1-Wire bus with more than one DS18B20. This allows for placing temperature sensors in many different places. Among the applications that can benefit from this feature are HVAC environmental control, monitoring and controlling equipment and machinery, and environmental sensors in buildings [27].

Figure 4.15: DS18B20

Lead acid battery- 12V 7.5A

Lead acid batteries are rechargeable batteries that run on lead and sulfuric acid. An equilibrium chemical reaction is created when lead is submerged in sulfuric acid. This chemical reaction is what causes the battery to produce electricity. The sulfate in the sulfuric acid bonds to the lead in the battery, which generates its electrical charge. Reversing this reaction replenishes the electrical charge. Sulphate is reabsorbed into sulfuric acid and, therefore, recharges the battery.

12V batteries are typically lead-acid batteries. A sulfuric acid solution suspends a lead plate in it. During this process, energy is stored through a chemical reaction. The flooded lead-acid battery is one of the most common types of lead-acid batteries [28].

Figure 4.16: Lead acid battery.

Features

- Voltage = 12V

- Capacity = 7.5 Ah
- Terminal Type = T2/T1
- L = 5.94 in x W = 2.56 in x H = 3.78 in (151 x 65 x 101 mm)
- Weight = 4.45 lbs (2.02 kg).

4.3. Implemented Models

Every system should follow the implementation procedure. Using the Proteus 8 simulation program, we first simulated the system. Next, we gathered all the parts and tools required to construct it. Finally, we connected the components following our simulation, and we created a hardware model.

4.3.1. Simulation Model

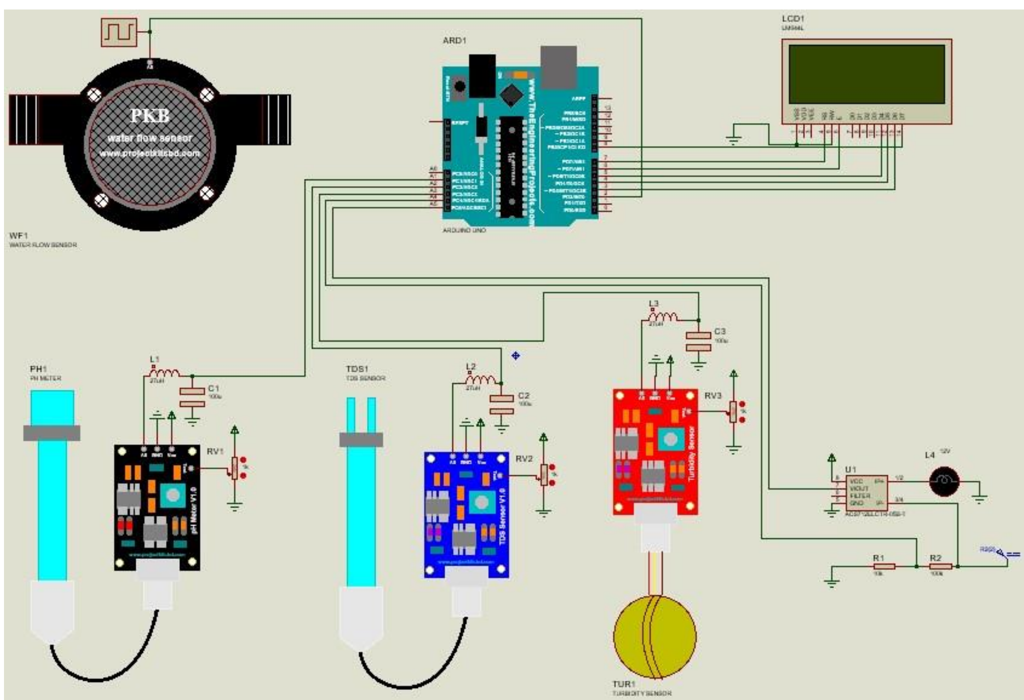


Figure 4.17: Simulation Model of the system

This is a simulation diagram for an Internet of Things water purification system that runs on solar power. Arduino Mega, LCD 2004, Water flow sensor, TDS sensor, turbidity sensor voltage sensor, and current sensor are using this simulation diagram.

4.3.2. Hardware Model

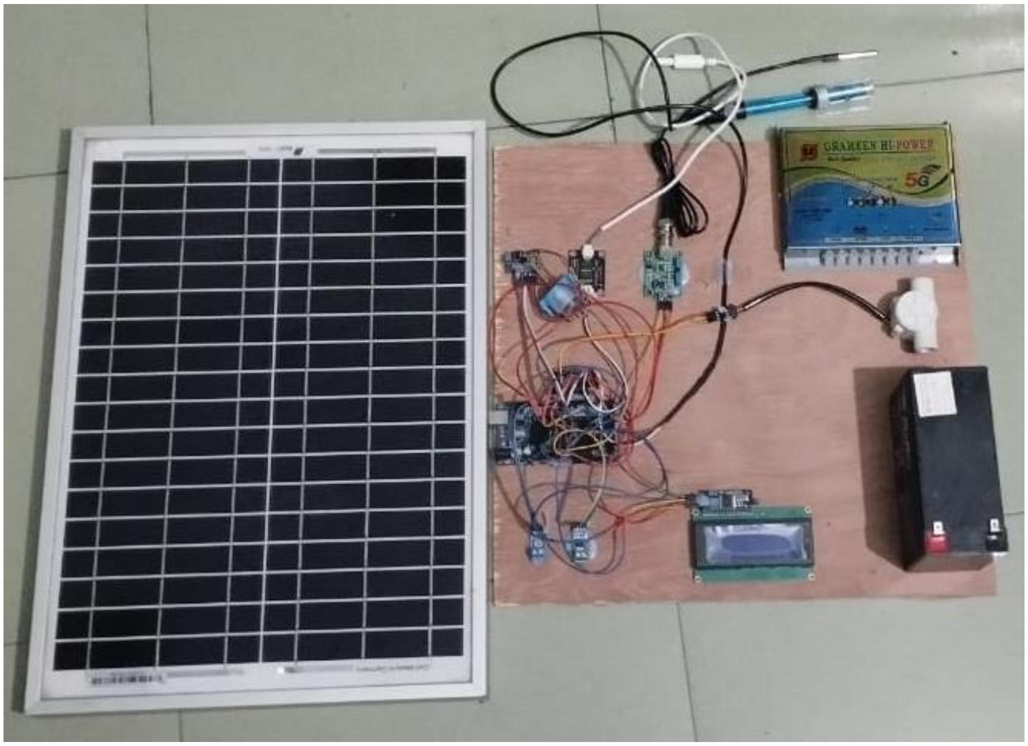


Figure 4.18: Hardware Model of the system

In this project, we are using a 20-watt poly crystal solar panel, 12 V 7.5 A Lead Acid Battery, Solar Charge Controller, pH Sensor, TDS Sensor, Turbidity Sensor, Voltage Sensor, Current sensor, water temperature sensor. Here Arduino Mega is the main controller of this project

4.4. Engineering Solution in accordance with professional practices

Engineering is a way to solve issues and make life simpler, but it's also important to look for solutions that can make people's lives safer. Making people's lives safer—or, maybe more accurately, making people feel safe when they drink water—is our suggested course of action. This project provides a method for purifying water in distant locations using solar energy. It discusses several professional engineering solutions as well as other engineering issues that have been resolved. Engineering solutions often have significant social effects. The main components of the project are the Arduino board, a variety of measuring sensors, and websites and applications that log the data collected. By comparing the measured data with the information permitted by this sector, we can ascertain the accuracy of the data we have received rapidly.

4.5. Summary

The equipment used for the project and how it was done are the main topics of this chapter. All components were employed in this chapter. Every component is seen above, complete with pictures and model specifications. This chapter includes a prototype approach for completing the major and secondary project goals.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1. Introduction

The project results section should function as a roadmap for the discussion part while providing an account of the findings without attempting to analyze, interpret, or appraise them. The results are providing insight into the analysis. Analysis and critical design review outcomes are distinct and project-specific. Every other project should adhere to this procedure. An engineering project adheres to a set pattern. For every other project, a simulation is needed first, followed by the collection of data and the construction of a prototype. It's time to compare the data after it's been gathered. There are notable differences between the hardware data and the simulation data. A comparison of simulation and hardware data is required to determine the success or failure of this endeavor. To complete this project, we first conducted a simulation. Once the simulation could be completed successfully, we took the data from the simulation and used it to inform our work on the hardware prototype. Once the prototype was complete, we compared the two sets of data and critically examined the design.

5.2. Analysis of Results

The project's outcomes section should make an effort to communicate the results without making an effort to assess or analyze them. It needs to act as a roadmap for the discussion portion as well. The analysis is highlighted by the findings that are given. Every engineering project should adhere to a set of procedures. In this example, the procedures are to run a simulation, collect data, then run hardware, and compare and evaluate the results. Thus, we do an in-depth analysis of both hardware and simulation data.

5.2.1. Simulated Results

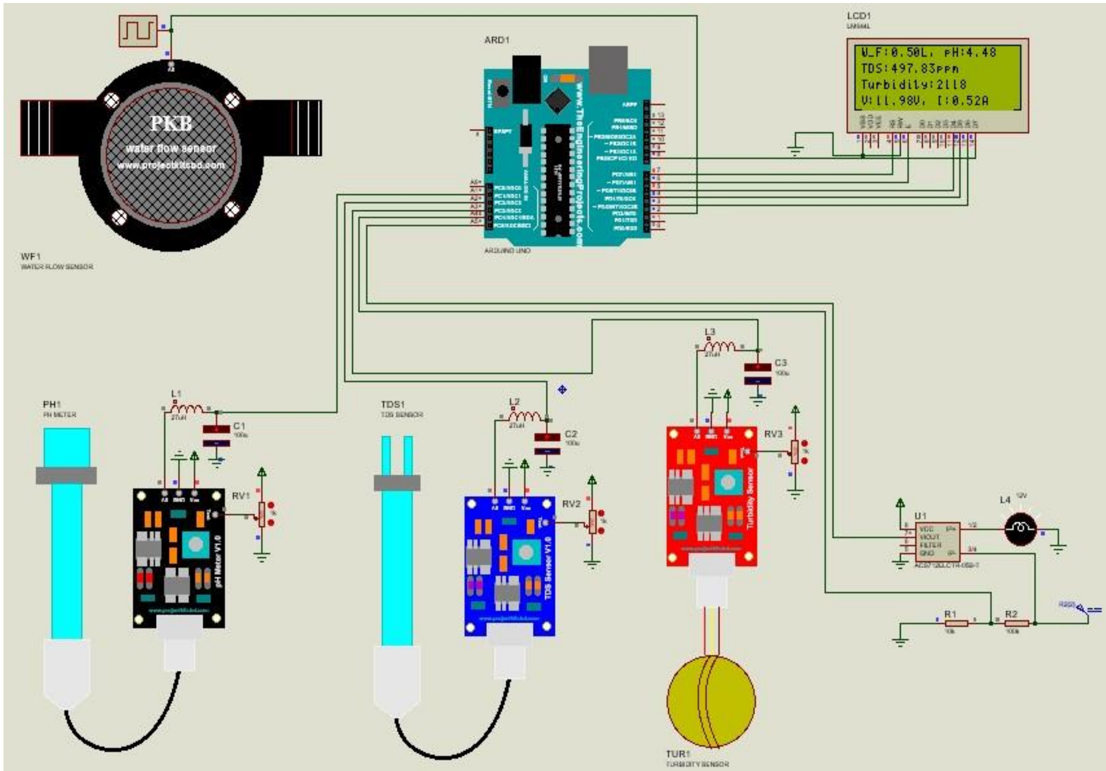


Figure 5.1: Simulation Result of the system

In this simulation result we can see, W_F: 0.50L, here W_F means Water flow. pH level is 4.48, TDS is 497.83 ppm, and Turbidity is 2118. V: 11.98 V, Here V means Solar Voltage and measured in voltage. I:0.52A, Here I means current and measured in Ampere.

5.2.2. Hardware Results

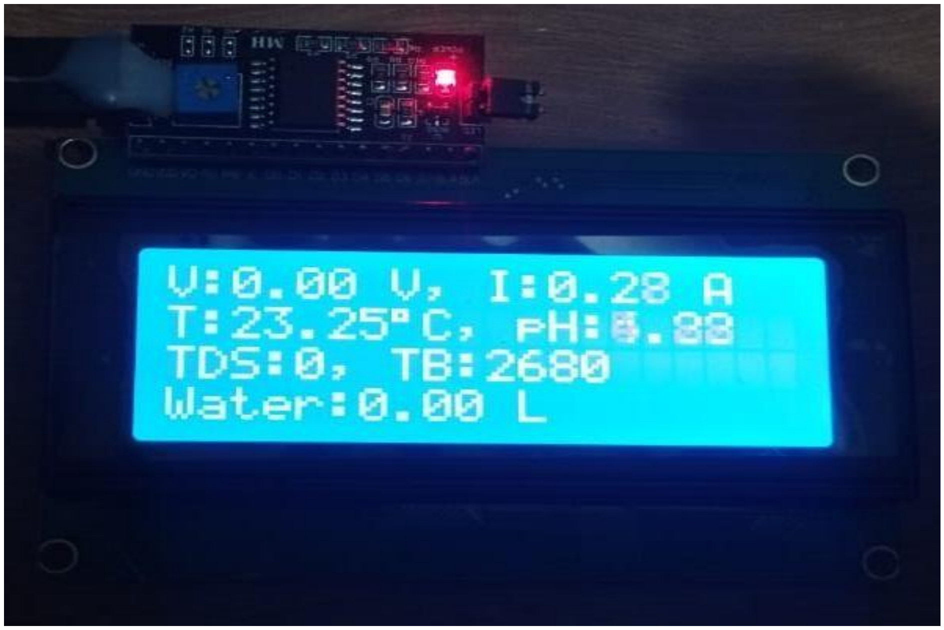
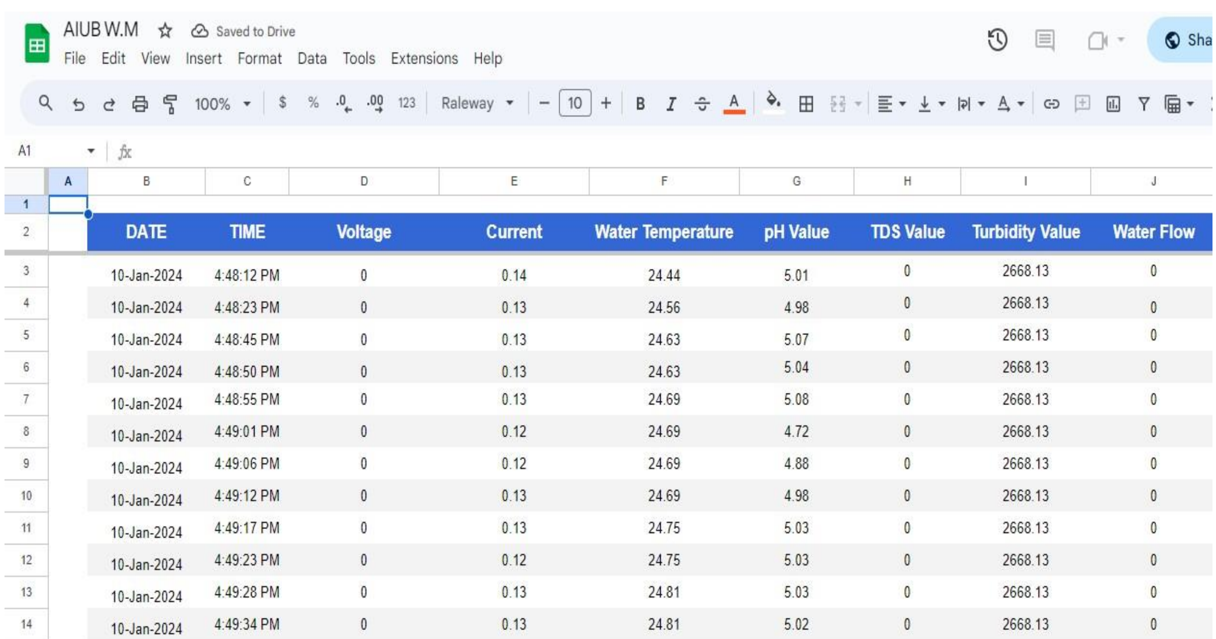


Figure 5.2: Output of the Project Display

In this hardware outcome, we can see that, W: 0.00L, here W means Water flow. pH level is 4.88, TDS is 0 ppm, and Turbidity is 23.25^{0}C. V: 0.00 V, Here V means Solar Voltage. I:0.28 A, Here I mean amp.



AIUB W.M

DATE	TIME	Voltage	Current	Water Temperature	pH Value	TDS Value	Turbidity Value	Water Flow
10-Jan-2024	4:48:12 PM	0	0.14	24.44	5.01	0	2668.13	0
10-Jan-2024	4:48:23 PM	0	0.13	24.56	4.98	0	2668.13	0
10-Jan-2024	4:48:45 PM	0	0.13	24.63	5.07	0	2668.13	0
10-Jan-2024	4:48:50 PM	0	0.13	24.63	5.04	0	2668.13	0
10-Jan-2024	4:48:55 PM	0	0.13	24.69	5.08	0	2668.13	0
10-Jan-2024	4:49:01 PM	0	0.12	24.69	4.72	0	2668.13	0
10-Jan-2024	4:49:06 PM	0	0.12	24.69	4.88	0	2668.13	0
10-Jan-2024	4:49:12 PM	0	0.13	24.69	4.98	0	2668.13	0
10-Jan-2024	4:49:17 PM	0	0.13	24.75	5.03	0	2668.13	0
10-Jan-2024	4:49:23 PM	0	0.12	24.75	5.03	0	2668.13	0
10-Jan-2024	4:49:28 PM	0	0.13	24.81	5.03	0	2668.13	0
10-Jan-2024	4:49:34 PM	0	0.13	24.81	5.02	0	2668.13	0

Figure 5.3: Output of IoT-Based Purification System using Solar Energy

In this Data Picture, we see the time, date, temperature, pH value, TDS value, Turbidity value, Water flow, voltage, and Current. Here we see 10 January 2024, time 4:48:12, Solar voltage was 0 V, Current 0.14 A, Water Temperature 24.44 C, pH value 5.01, TDS Value 0, Turbidity Value 2668.13, and Water Flow 0 L.

Then, here we see 10 January 2024, time 4:48:23, Solar voltage was 0 V, Current 0.13 A, Water Temperature 24.56 C, pH value 4.98, TDS Value 0, Turbidity Value 2668.13, and Water Flow 0 L.

Then, here we see 10 January 2024, time 4:48:45, Solar voltage was 0 V, Current 0.13 A, Water Temperature 24.63 C, pH value 5.07, TDS Value 0, Turbidity Value 2668.13, and Water Flow 0 L.

5.3. Evaluation of the Results Comparing

The simulated results are quite dissimilar to the hardware results. In the simulation result we can see, W_F: 0.50L, here W_F means Water flow. pH level is 4.48, TDS is 497.83 ppm, Turbidity is 2118 NTU. V: 11.98 V,
Here V means Solar Voltage. I:0.52A, Here I means current. Besides hardware outcome we can see that, W: 0.00L, here W means Water flow. pH level is 4.88, TDS is 0 ppm, Turbidity is 23.25 NTU. V: 0.00 V, Here V means Solar Voltage. I:0.28 A, Here I means current.

5.4. Summary

In summary, the aforementioned model has the ability to purify water according to various parameters. This chapter covers the project's objectives, development, and outcomes. Upon testing, this project proved to be operating in accordance with the specifications specified in the design. The functional specifications were met. This chapter included the required system design, data analysis, and result comparison and interpretation. The expected outcome was successful. The simulation run successfully. Not much was changed in the hardware to get the expected outcomes. The hardware's outcome and the simulation's result were comparable. The project's overall impression was given last.

Chapter 6

CONCLUSION

6.1. Summary of Findings

It is essential to understand the system behavior of each project component to provide a temporary layer of security. A renewable energy-powered water purifying system is the main objective of the project. By using the website and applications, users will be able to monitor their everyday water, solar power, also additional energy usage, in addition to the amount of power desirable aimed at this project. The data can be viewed on our website or through our applications in real time. In this way, we will be able to live safer and easier lives. This project purposes to progress an IoT-based system for power consumption monitoring and water purification. The project design will be improved and made more efficient through the use of this system that can detect voltage, current, pH, and water flow among other things. Even though the intended project effort will benefit society, the hardware and simulation results suggest it will be beneficial. Consequently, the recommended system could be beneficial and significant for people to use daily based on the results of each simulation and hardware model.

Since solar energy is widely available and inexpensive for purifying water, it may be utilized anywhere that power is unavailable. Here, the water overflow is also stopped by the microcontroller that's being used. Reverse osmosis is also a useful disinfection technique. This project has very little ongoing costs and only capital expenditures. For this reason, it will come in handy soon.

6.2. Novelty of the work

Every project has a few unique elements that add to its intelligence and efficacy. The project may be exceptional due to its unique features. Through the aforementioned project, we were able to show how unique features may be integrated with a conventional water purification system to create an IoT system for monitoring water and energy usage. Even though the project appears well-known in modern times, most individuals are unable to access it since it is not now available in Bangladesh. In addition to increasing access to clean water, the project aims to educate the public on the importance and uses of this resource. Additionally, it has the ability to monitor the power consumption of that specific device. Users gain from a number of unique characteristics that make the job beneficial and secure to utilize. The concept uses a range of sensors in order to function effectively and efficiently. Water flow, pH, voltage, and current can all be monitored by the sensors. Websites and applications provide administrators with access to their real-time data. IoT-based water and power monitoring systems based on contemporary technologies can be transformed into a straightforward, conventional water purifying system by using contemporary technologies. With these distinctive traits, people will be able to lead a flexible, straightforward life every day.

6.3. Cultural and Societal Factors and Impacts

The results of this attempt are felt by the users of this technology in many ways. Cultural and economic considerations are made at every stage of the design process. We also looked at the different factors that this project considered. To achieve optimal outcomes through the gathering and use of data from every sensor. There will be several more long-term effects of the program. Technologies that offer a multitude of comforts and conveniences will be beneficial to society. The user interface for this project needs to be improved. We have also investigated complex engineering issues, addressing the challenges with a range of models or sub-problems. Engineering concepts were developed with a methodical, theory-based approach. Housing, population, and economic situations as they currently exist might be improved by this initiative. Members who work in this field will develop more self-confidence, willpower, and curiosity. The goal of developing the model was to give the user incredibly precise results. To obtain an accurate result, monitoring every location might be helpful. With a range of sensors, depending on their efficiency and mode of operation, this project will improve the speed at which the amount, quality, and consumption of water may be rapidly determined at a fair cost.

6.4. Work Limitations

Every research endeavor that is being developed has some limitations. Our project is the same as that. Both software and hardware have been used to implement the entire project. We have measured values from both the hardware and the simulation models. We could not test this project in rural areas, even though that is where we intended it to be implemented. We tested it in our room with tap water. Even if this prototype cannot be utilized in rural regions, it must be made smaller, like a chip. We may then apply this to rural regions after that. There are several restrictions when it comes to project construction because this is a final assignment for university credit. A number of challenges emerge as the project progresses. The underlying causes are as follows:

- There is a time restriction.
- It cannot access to real time water parameters in the data sheet without strong network.
- The purification cannot be done perfectly in case of highly turbid water.

6.5. Future Scopes

Further testing is required before this prototype model is made available for purchase. It may be utilized outside the house in the near future to track solar-powered activities and assess water purification. The majority of the time, this strategy will be applied in rural areas. As a result, system administrators can monitor and understand how data is used in real time. In Future, we will test this project in rural areas, even though that is where we intended it to be implemented. But we could not test this. We tested it in our room with tap water. We will work to decrease the limitations of our project. Following works can be done in future:

- A Reverse Osmosis system can be added in this existing project to get the better performance on purification system.
- The size of the project can be reduced so that it can easily transport and utilize in rural regions.
- The complexity of the project can be reduced.

6.6. Social, Economic, Cultural and Environmental Aspects

When this initiative was being created, a number of ethical considerations had to be addressed. In order to make judgments that would uphold the ethics of the task, the approach was ethically assessed. Some guidelines have to be adhered to.

6.6.1. Sustainability and Standard Requirements

Elemental Water Makers wants to use just the sea, sun, earth, and wind to address the fresh water shortage. Elemental Water Makers wants to help people who live on islands or in coastal areas but are currently unable to sustainably satisfy their water demands by offering off-grid solar desalination technologies. Resilient and sustainable water solutions can deliver inexpensive clean water by fusing technology-driven desalination systems that exploit the sun, earth, and other resources with a people-centered strategy that attends to local requirements and guarantees autonomous operation and maintenance.

This directly supports both the sustainable use of marine resources (SDG14) and the availability and sustainable management of water (SDG 6). Particularly, elemental water producers can offer water resilience for archipelagos and small island developing states (SIDS) to respond to drought events and calamities. Countries like the Philippines, where fresh water supplies are running low and droughts are happening more regularly, are leading the way in terms of climate change. A lot of beneficial side effects are also a result of SDG6 acceleration.

For example, making water more accessible and affordable cuts down on the time and costs associated with obtaining it from other sources—a chore that is frequently assigned to women and children. Women and children may now more easily gather water, which frees up more time for them to devote to education and personal growth. This promotes gender equality and the amount of time spent on education. Furthermore, maintaining a high standard for drinking water promotes overall health and well-being by lowering the risk of catching avoidable water-related illnesses including cholera and diarrhea (SDG3).

Since a steady supply of water makes it possible to exploit land for agriculture in areas where rainfall was previously insufficient, the provision of clean water also encourages local economic growth. A greater supply of water also enables local business owners to sell water to homes and businesses (SDG 8), which when combined strengthens the ability of isolated communities to withstand the mounting strain that population expansion and climate change place on freshwater resources (SDG 11& 14). When a nation's unemployment rate is as high as it is—17%—and the majority of its labor force is employed in industries that depend on fresh water, like agriculture, economic development is especially important (Central Intelligence Agency, 2018; The Economist, 2017) [29].

6.6.2. Health and Safety

This project technique does not pose a health risk to anyone. This work has appropriately respected the principles of health and safety. There isn't a single hazardous tool that might pose a health risk. In order to fulfill ethical duties and provide an engineering solution, this project upholds engineering norms and principles. People will be more capable of taking care of their health as they may use this study to ascertain the water's purity. Health and safety for the public must be guaranteed.

6.6.3. Economy and Environment

This project technique does not pose a health risk to anyone. This work has appropriately respected the principles of health and safety. There isn't a single hazardous tool that might pose a health risk. In order to fulfill ethical duties and provide an engineering solution, this project upholds engineering norms and principles. People will be better equipped to take care of their health since they can use this study to identify the water's quality. Health and safety for the public must be guaranteed.

6.7. Conclusion

One of the requirements listed for the life of people, animals, and plants is water. There could not be life without water. Bangladesh's major dams and rivers frequently have dangerously low water levels, which restricts the amount of drinking water that is available to consumers, particularly in rural regions. In many places, connecting to the electrical grid is also difficult. The goal and philosophy of the project were both accomplished. To maximize the potential of our technology, we have worked hard and studied the subject matter thoroughly. The proposed project endeavor aligns with the goal of contemporary science and technology, which is to improve the quality of life and comfort of those who are less fortunate. Giving individuals independence and autonomy is the primary goal of this endeavor. Programs such as PROTEUS were used to simulate the structural designs for this project, with Arduino functioning as the primary control component. The approach has also been implemented using hardware. The recommended setup creates a real-time system that is capable of detecting power, pH, voltage, current, and water flow by combining several helpful components. To track the data gathered, we also developed an app and website. These improvements ensure the security, safety, and intelligence of the system. Users of this gadget may track their daily usage in a personalized manner because all of these apps are connected.

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Appendix A

iThenticate Plagiarism Report

IOT Based water purification.

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