Fabrication and Performance Evaluation of a Circular Section Solar Operated Water Heating System

A report submitted to the Department of Mechanical, Sonargaon University of Bangladesh in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Mechanical Engineering

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ABSTRACT

Solar energy is getting popular nowadays. Technologies have been developed which made solar energy a cheaper and reliable source of energy. Due to pollution and other factors, solar has become the most popular source of energy. Along with power generation, now water heaters are also developed which are working on the solar technology. It is a reliable method and can be used in areas which do not have access to wood, coal and gas. This project is based on design and fabrication of solar water heater. In this project, active water heaters are employed which way. Copper Pipe of both is oval and rectangular used to compare the heat transfer. A motor will be suck water from reserves tank to hot water tank and galvanized iron pipe will be heated from the sun light. Local materials and manufacturing methods were used to fabricate the solar water heater to limit the cost of project. At the end impact of the project was discussed on social, economic and environmental grounds.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

This project is intended to design a water heating system by using solar technology. There are various design and manufacturing constraints but here the most general and efficient way would be used. It includes thorough study of the mechanism of the solar water heater. After designing such mechanism, the heater would be manufactured, and the results would be presented. Solar energy technology is used in various places in different ways. It is used to produce electricity and it provides energy which is used to cook food. Solar systems are designed in such a way that water can be heated to any temperature [1].
But at domestic levels water can be heated up to 60 ºC. Evaculed types of solar heaters and glazed plate heaters are the most common types of solar powered water heaters used in the world. Some of the systems are active and others are passive. Active systems are divided into direct and indirect solar systems. In this project indirect solar system will be designed.

The world relies heavily on fossil fuels for most of its energy demands, and this has caused a lot of harm to the Earth. The increase of green-house gas levels in the atmosphere is largely due to the combustion of fossil fuels as a source of energy[2]. This has caused global warming which has led to climate change, floods, forest fires, rising sea levels and the melting of glaciers. These are just some consequences of the overreliance on fossil fuels for our energy demands. Solar energy provides an alternative and environmentally friendly energy source to the fossil fuels used for our energy needs. Over the last few decades, solar energy systems have gained more recognition because they can provide energy at a low long-term cost and minimal environmental damage.

Researchers have developed several techniques for harnessing solar energy, these techniques include applications for space heating, water heating, electricity generation and many others[3]. Solar energy is generated by the fusion reaction of hydrogen atoms in the sun. This fusion reaction results in the release of high-energy particles called gamma rays. Gamma rays are transmitted as electromagnetic radiation to the Earth, which is at about 150 million kilometers from the sun. Electromagnetic radiation comes in three forms: infrared rays, visible light, and ultraviolet rays. Solar energy reaching the Earth’s surface can be

harnessed directly by using photovoltaic (solar cells) and solar concentrators[4]. Photovoltaic are used for electricity generation, while solar concentrators are used as a source of thermal energy. The utilization of solar energy collectors (concentrators) to transform radiation into heat energy is the basis of the solar water heating technology. A simple solar water heater consists of a collector, a tank, and the flow channel through which the working fluid is transported.

1.2 Problem Statement

Considering the epileptic nature of electric power supply in our country, the reliance on solar applications for water heating will lead to better reliability of service for hot water needs and will have minimal negative impact on the environment. This would reduce the reliance on electric heaters, which have higher operational costs and depend on fossil fuels as a primary energy source.

1.3 Motivation for the Study

A lot of research has gone into the solar energy field over the past few decades. This is mostly because of the increased world-wide acknowledgement of the environmental effects that the use of fossil fuel as an energy source comes with. This current study would result in the design and construction of a portable solar water heating system which would provide hot water. The use of locally sourced materials would reduce the financial resources required compared to the importation of these materials. With this system our country going through a recession and a pandemic which has further impacted the nation's economy, the availability of locally made solar water heating systems would help boost the local economy and curb the rate of importation.

1.4 Objective

The objectives of this thesis are:

- To design and fabricate a Circular Section Solar Water Heater
- To carry out the performance evaluation of the constructed solar water heater.

1.5 Structure of the Project

Chapter 1 Introduction: The first chapter contains the statement of the introduction, problem statement, motivation of our study, objectives and the project outline.

Chapter 2 Literature Review: The chapter two contains introduction, about solar water heater theory, types of solar water heater, literature review part and summary.

Chapter 3 Hardware and Software Analysis: Chapter three describes the theoretical model. Here we mainly discuss about proposed system about Hardware.

Chapter 4 Methodology: Chapter four deals with our project methodology, working steps, block diagram, structural design, working principle.

Chapter 5 Result and Discussion: Chapter five deals with our project discussion, result part of our project advantages and our project application study.

Chapter 6 Conclusion: Chapter six all about our project conclusion and future scope.

CHAPTER 2
LITERATURE REVIEW

2.1 Solar Water Heater

Solar water heater the conversion of sunlight into renewable energy for water heating using a solar thermal collector. Solar water heating system comprises various technologies that are used worldwide increasing. In a "close-coupled SWH system the Storage Tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank thought thermos siphon flow. In a "pump-circulated" system the storage tank is ground – or floor – mounted and is below the level of the collectors; a circulating pump moves water or heat transfer fluid between the tank and the collector [5].

A Solar Water Heater is a device which provides hot water for bathing, washing, cleaning, etc. using solar energy. It is generally installed at the terrace or where sunlight is available and heats water during day time which is stored in an insulated storage tank for use when required including morning. We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society.

One of the popular devices that harness the solar energy is solar hot water system (SHWS). A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water [6]. The solar energy incident on the absorber panel coated with selected coating transfers the hat to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and is delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to 80 C (Maximum) in a good sunny day [7].

The total system with solar collector, storage tank and pipelines is called solar hot water system. Broadly, the solar water heating systems are of two categories. They are: closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from bore wells or from freezing temperatures in the cold regions.

2.2 Types of Solar Water Heaters

Solar water heaters can be either active or passive. An active system uses an electric pump to circulate the heat transfer fluid; a passive system has no pump. The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, proper installation, and the tilt angle and orientation of the collectors. Solar water heaters are also characterized as open loop (also called “direct”) or closed loop (also called “indirect”). An open-loop system circulates household (portable) water through the collector. A closed-loop system uses a heat transfer fluid (water or diluted antifreeze, for example) to collect heat and a heat exchanger to transfer the heat to household water.

2.2.1 Active Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heattransfer fluids through the collectors. They are usually more expensive than passive systems but are also more efficient. Active systems are usually easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. But because they use electricity, they will not function in a power outage.

Active systems range in price from about $2,000 to $4,000 installed.

2.2.2 Open-Loop Active Systems

Open-loop active systems use pumps to circulate household water through the collectors. This design is efficient and lowers operating costs but is not appropriate if your water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in nonfreezing climates such as Hawaii. They should never be installed in climates that experience freezing temperatures for sustained periods. You can install them in mild but occasionally freezing climates, but you must consider freeze protection. Re circulation systems are a specific type of open-loop system that provide freeze protection. They use the system pump to circulate warm water from storage tanks through collectors and exposed piping when temperatures approach freezing. Consider re circulation systems only where mild freezes occur once or twice a year at most. Activating the freeze protection more frequently wastes electricity and stored heat. Of course, when the power is out, the pump will not work and the system will freeze. To guard against this, a freeze valve can be installed to provide additional protection in the event the pump doesn’t operate. In freezing weather, the valve dribbles warmer water through the collector to prevent freezing.

2.2.3 Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Double-walled heat exchangers prevent contamination of household water. Some codes require double walls when the heat transfer fluid is anything other than household water.

2.2.4 Passive Systems

Passive systems move household water or a heat-transfer fluid through the system without pumps. Passive systems have no electric components to break. This makes them generally more reliable, easier to maintain, and possibly longer lasting than active systems. Passive systems can be less expensive than active systems, but they can also be less efficient. Installed costs for passive systems range from about $1,000 to $3,000, depending on whether it is a simple batch heater or a sophisticated thermo siphon system.

2.3 Literature Review

The solar energy that the Earth receives in a day is far greater than the total amount of energy that humans use up in the same time period. Eighteen days of the incident solar radiation on Earth would give an equivalent amount of energy when compared to all the planet's reserves of natural gas, coal and oil (Union of concerned scientists, 2015). Outside the earth's atmosphere, solar radiation contains about 1,300 watts per square meter. A third of this gets reflected into space once it reaches the earth's atmosphere, the rest travels toward the surface of the earth [4]. On average, over the earth's surface, every square meter receives about 4.2 kilowatt-hours of solar energy in a day (Union of concerned scientists, 2015).

Although the solar energy received by the Earth daily is greater than amount used by humans, the intensity of this solar energy or radiation incident on the Earth's surface depends on some factors. These factors include the geographic location and its inherent climate, the weather patterns or season and the time of day. At certain periods within the year, the Earth is near the sun, this is because the Earth revolves elliptically around the sun [5]. When the Earth is nearer the sun, its surface receives a higher amount of solar radiation. Earth's rotation around the sun is on a tilted axis of 23.5° and this plays a role in determining the incident radiation

at a given location. For the six months within the two equinoxes, the Earth's tilted rotation brings about longer daytime in the northern hemisphere. The southern hemisphere on the other hand, has longer days for the six months after the fall equinox [6]. The southern parts of the United Kingdom and other middle latitudes get higher amounts of radiation during summer due to the longer days.

However, during winter, regions around the middle latitude receive lower amounts of solar energy because the solar rays are incident at a tilted angle during winter in middle latitude regions (Office of energy efficiency and renewable energy, 2013). The intensity of the solar radiation received on the earth's surface depends on the angle the sun's rays make with the earth's surface. This angle ranges from 0°: when the sun is just above the skyline, to 90°: when the sun is directly overhead. The greatest intensity of solar radiation striking the Earth's surface can be observed at solar noon [7]. This is when the sun is at its highest position (90°) in the sky, on a clear, cloudless day (Energy information administration, 2020). At angles less than 90°,the solar rays travel longer distances through the atmosphere, making them less intense by the time they reach the Earth's surface.

As solar rays travel through the Earth's atmosphere, some rays get absorbed or reflected and others get scattered. Various elements such as the air molecules, water vapour, the clouds, dust particles and volcanoes influence whether the solar rays get absorbed, reflected, or scattered. Based on this, solar radiation is classified into two components, diffuse and direct beam solar radiation. Direct beam rays reach the earth's surface without being diffused [8]. Diffuse rays get scattered, absorbed or reflected by the dust particles, air molecules or water vapour in the Earth's atmosphere (Adefarati & Bansal, 2019).

When the solar collector of a SWH is inclined, the diffuse rays striking it comprises the sky diffuse radiation, and a third component of solar radiation: Ground reflected radiation (Ineichen et al., 1990). The ground reflected radiation reflects off the earth surface and strikes the collector. The direct radiation gets affected by atmospheric conditions, on a clear, dry day it can reduce by up to 10% and during thick, cloudy days, by up to 100% (Office of energy efficiency and renewable energy, 2013) [9]. Global solar radiation is the total amount of solar energy the earth's surface receives, it is equivalent to the sum of the diffuse, direct beam and ground reflected radiation.

While concentrating solar systems require direct beam solar radiation to function properly, the flat-plate collector system functions properly with both the diffuse and direct beam solar radiation (Energy information administration, 2020). Scientific researchers record the amount of solar radiation incident on specific locations at various periods during the year. These values are used to estimate the amount of solar radiation incident in other locations with similar latitudes and local weather [10]. Solar energy measurements are usually expressed as the total amount of solar radiation on a horizontal surface, or as the total solar radiation on a surface tracking the sun. Solar radiation data is usually represented as kilowatt-hours per square meter (Office of energy efficiency and renewable energy, 2013).

CHAPTER 3
HARDWARE AND SOFTWARE ANALYSIS

3.1 Plastic Pipe

Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances which can flow liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members.

Product Description:

Product Name:	clear pvc tubing pvc from 1/8inch(ID
Material:	3mm) to 2inch (ID 50mm) from
Size:	1mm to 4mm
Wall Thickness:	clear / blue / red / yellow / black / green / orange etc.
Color:	from 2bar (30psi) to 4bar
Working Pressure:	(60psi) from -5 to 65
Temperature Range:	degree C.
Length/roll	10m, 20m, 30m, 50m/roll or other.

Application:

Suitable for low pressure transfer of various Fluids and air, such as fuel, water, light chemicals, oxygen, gas for watering systems, peristaltic pumps, electrical and thermal insulation, analytical systems in plant equipment, laboratories, watering system and many other low pressure industry applications.



Figure 3.1 : Plastic Pipe

3.2 Temperature Meter

A temperature meter is an instrument used to measure the temperature of beings or things. The most widely recognized temperature meter is a mercury thermometer used to measure the temperature of people.



Figure 3.2: Temperature Meter

Specification

- Temperature range: -50~ +110°C

Using environment:

- Temperature: -5~ +50°C
- Humidity: 5%~80%
- Accuracy: ±1°C
- Size: 47*28*14mm
- Weight: 22g
- Color: Black and white

3.3 Pump Motor



Figure 3.3: Pump Motor

- Power:16.8W
- Max Flow Rate: 700 L/H
- Max Water Head: 5M Max
- Circulating Water Temperature: 60°C

Specification:

- Material: ABS(Acrylonitrile Butadiene Styrene) Stainless Steel
- Overall Size: Approx. 80 ×48 ×2.48" 63mm/3.15 x1.89
  - Pump Inlet Diameter: 16mm(Outer), 12mm(Inner)
  - Pump Outlet Diameter: 12mm(Outer), 6.9mm(Inner)
  - Inlet/Outlet: 1/2" male thread
  - Voltage: 6-12V DC
  - Maximum Rated Current: 1.2A
  - Power:16.8W
  - Max Flow Rate: 700 L/H
  - Max Water Head: 5M
  - Max Circulating Water Temperature: 60°C

3.4 Solar Cell

These panels are designed with solar cells composed of semiconductor materials. The main function of Solar panels is to convert solar energy into DC electrical energy generally of 12V, which is further used for the rest of the circuit.



Figure 3.4: Picture of solar sell system.

Specifications:

Model: SP-10W

Rated Power (Pmax): 10 Watts

Open Circuit Voltage (Voc): 21.6 Volts

Short Circuit Current (Isc): 0.65 Amps

Maximum Power Voltage (Vmp): 18 Volts

Maximum Power Current (Imp): 0.56 Amps

Cell Type: Monocrystalline / Polycrystalline

Panel Dimensions: 350 mm × 250 mm × 17 mm (L × W × H)

Weight: Approx. 0.8 kg

Operating Temperature Range: -40°C to +85°C

Frame: Aluminum frame with tempered glass

Junction Box: IP65 rated, with bypass diodes

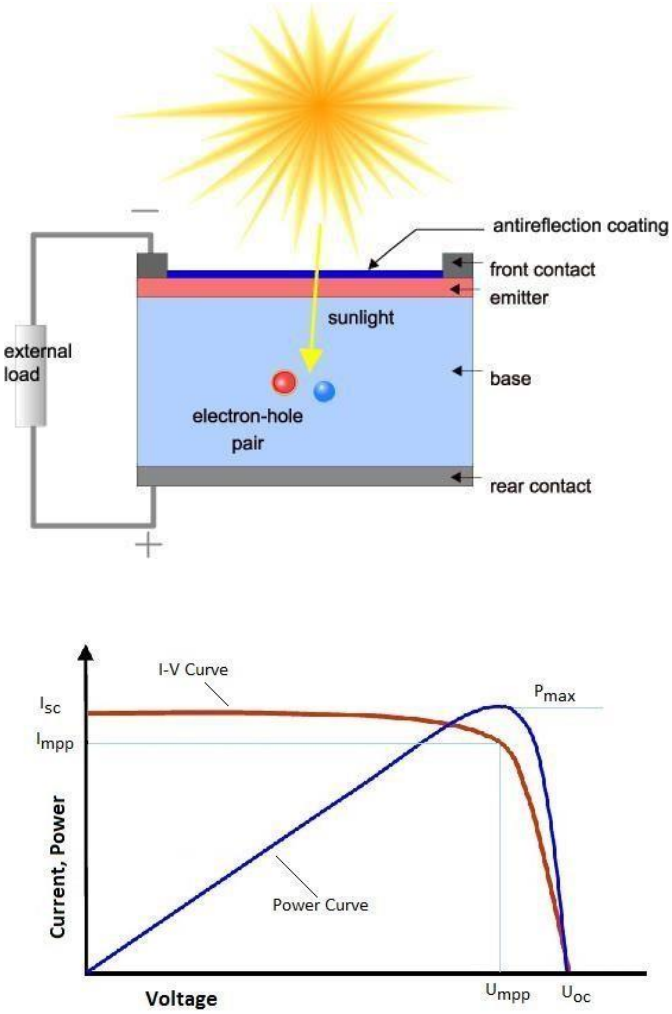


Figure 3.5: Solar sell system Curve.

3.5 Arduino Nano

Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling Lights, motors, and other actuators.

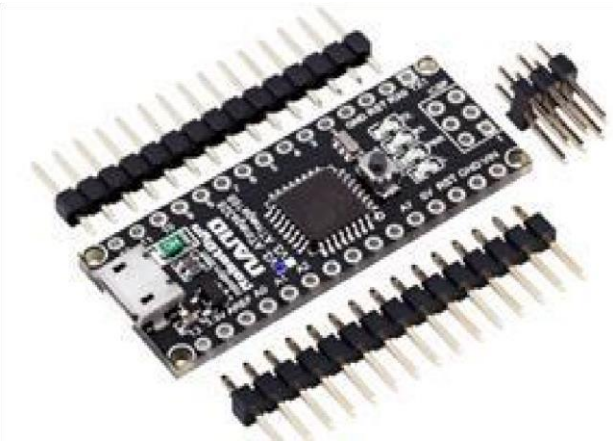


Figure 3.6: Arduino Nano

The micro-controller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, Maxims'). Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a small, complete, and breadboard friendly component. It has everything that Decimal/ Duemilanove has (electrically) with more analog input pins and onboard +5V AREF jumper. Physically, it is missing power jack. The Nano can automatically sense and switch to the higher potential source of power.

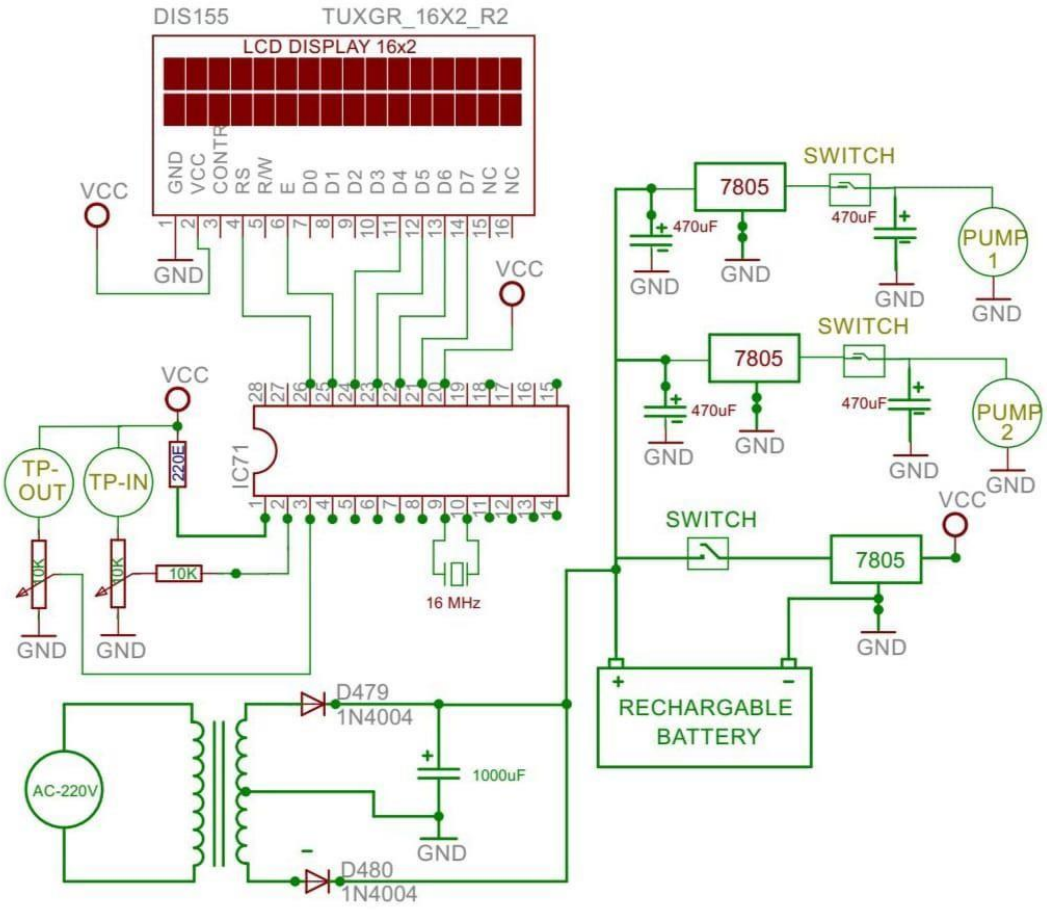


Figure 3.7: Arduino Nano Schematic Diagram

Nano's got the breadboard-ability of the Boarding and the Minibus with smaller footprint than either, so users have more breadboard space. It's got a pin layout that works well with the Mini or the Basic Stamp (TX, RX, ATN, and GND on one top, power and ground on the other). This new version 3.0 comes with ATMEGA328 which offer more programming and data memory space. It has two layers. That make it easier to hack and more affordable.

One of the best features of Arduino Nano is, it's easy to use, compact and also small.

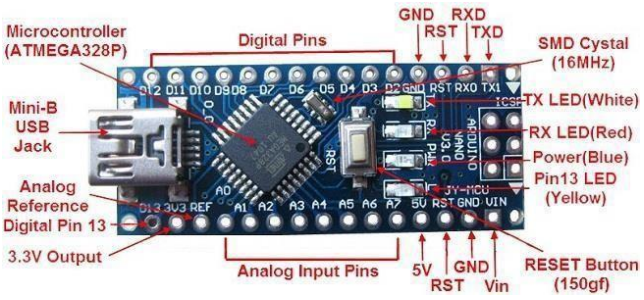


Figure 3.8 : How Arduino Nano looks like

Specifications:

- Micro-controller: Atmel ATmega328
- Operating Voltage (logic level): 5 V
- Input Voltage (recommended): 7-12 V
- Input Voltage (limits): 6-20 V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB (of which 2KB used by boot loader)
- SRAM : 2 KB
- EEPROM: 1KB
- Clock Speed: 16 MHz
- Dimensions: 0.70” × 1.70”

Features:

- Automatic reset during program download
- Power OK blue LED
- Green (TX), red (RX) and orange (L) LED
- Auto sensing/switching power input
- Small mini-B USB for programming and serial monitor
- ICSP header for direct program download
- Manual reset switch

Micro-controller IC ATmega16-16PU

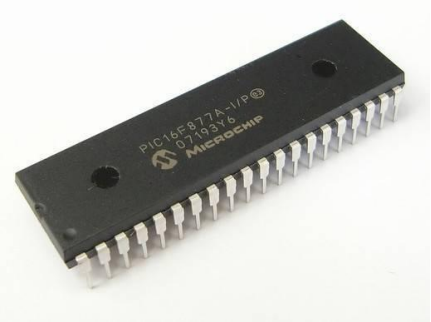


Figure 3.9: Micro-controller IC ATmega16-16PU

The high-performance Microchip Pico Power 8-bit AVR RISC-based micro-controller combines 32KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, a 6channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. By executing powerful instructions in a single clock cycle, the device achieves throughput's approaching 1 MIPS per MHz, balancing power consumption and processing speed.

CHAPTER4

METHODOLOGY

4.1 Our methodologies for the project

Our methodologies for the project:

- Creating an idea for design and construction of an Fabrication and Performance Evaluation of Rectangular and Oval Cross Section Solar Water Heater**.** And designing a block diagram & structural diagram to know which components we need to construct it.
- Collecting all the components of our system.
- Setting up all the components in a PCB board & then soldering. Lastly, assembling all the blocks in a board and to run the system & for checking purposes.

4.2 Working Step Chart

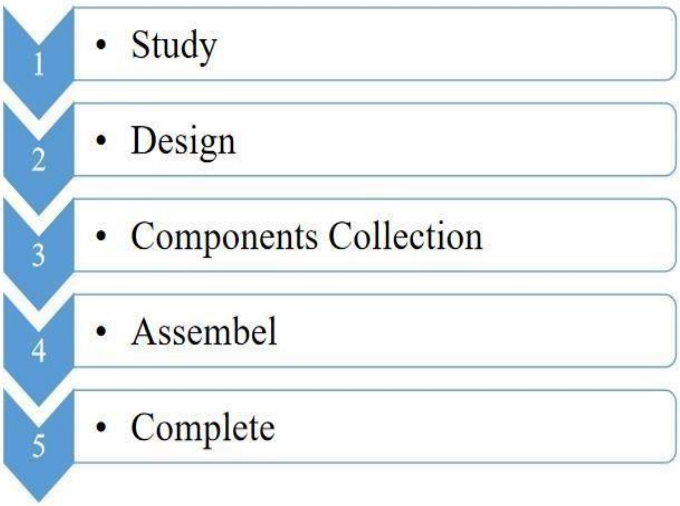


Figure 4.1: Working Step Chart

4.3 Block Diagram

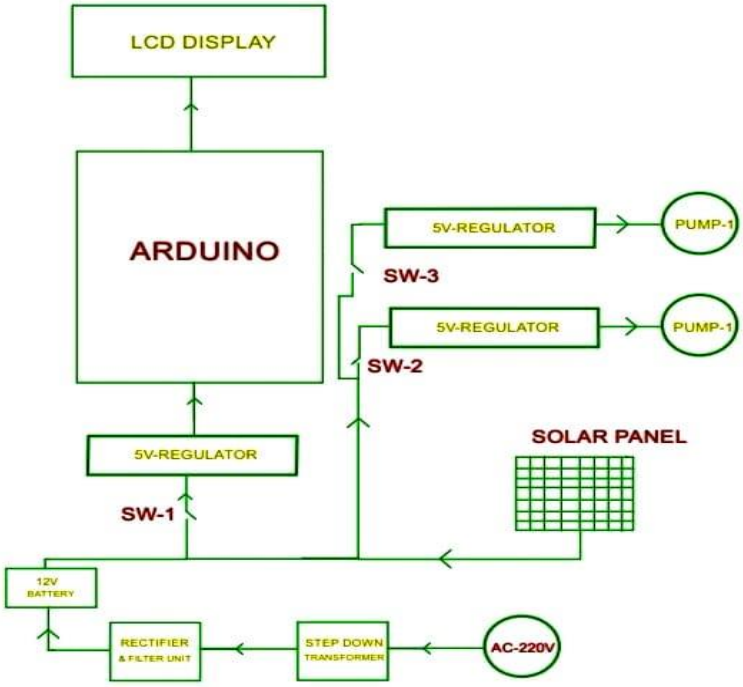


Figure 4.2: Block Diagram of Our System

4.4 Structural Design

The schematic diagram here is representing the electrical circuit and the components of the project. Here we have used standardized symbols and lines.

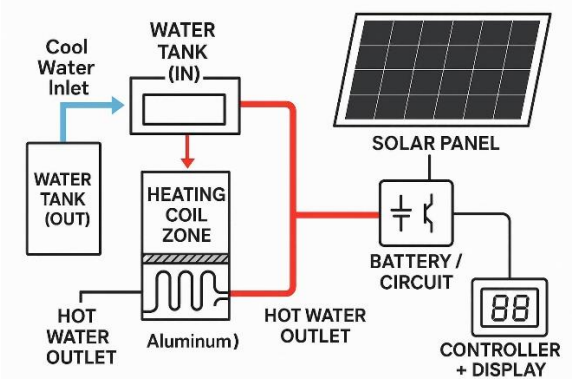


Figure 4.3: Structural Diagram of the Project

4.5 Working Principle

Solar panel generate the power supply fixed 5V DC, 5Amp in this system. Here we use Pump motor, Oval Pipe and Rectangular pipe Reserve tank, hot water tank etc. In this system we will heat water mainly by using solar energy. Here we use pump motor, Oval Pipe and Rectangular Pipe, arduino show the Temperature Sensor meter in temperature, Reserve tank etc. Water will enter from the reserve time by pressing the toward through the pump and there the temperature of the water will be measured with a temperature sensor. Reserve tank water is normal. After reach the MS Rectangular Pipe water will be heated and goes heated water tank and store it for future uses. MS Rectangular Pipe will absorb heat from sun. This is the main purpose of this system.

4.6 Final System View

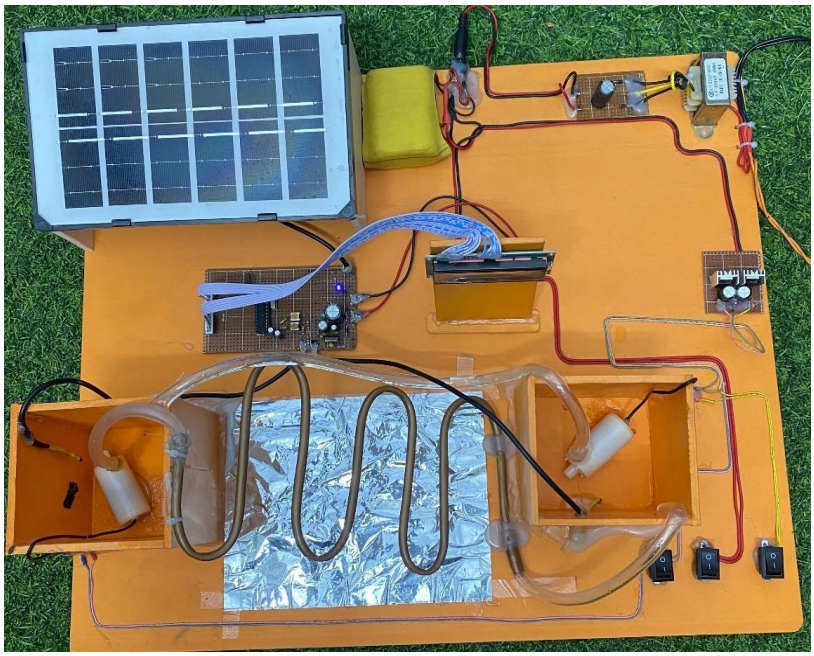


Figure 4.4: Final System Overview (Top View)

CHAPTER 5

RESULT AND DISCUSSION

5.1 Result

Efficiency Calculation:

Where:

Pout = 10 W (rated power)

Pin = 1000 W/m² (standard sunlight irradiance)

A = Area in m² = (0.35 m × 0.25 m) = 0.0875 m²

Efficiency = $\left(\frac{P(out)}{P(in)\times A}\right)100$

$= \frac{10}{1000\times 0.0875} \times 100 \approx 11.43\%$

IDE and the following things can happen:

- After power this project then it will be able to operate.
- Here we use a submersible pump to flow our liquid.
- Reserve tank water is normal.

After starting flow of water trough pump it will get hot from the heat of Copper Pipe and store in hot water tank.

All the normal and heated water data were collected.

Table 1 : Change in Temperature

Time	Input(℃)	Output(℃)	Change in Temperature Percentage(%)
01:16 pm	29.1	29.7	2.06%
01:19 pm	29.3	29.8	1.71%

01:23 pm	29.4	29.9	1.70%
01:25 pm	29.5	30.1	2.03%
01:27 pm	29.6	30.4	2.70%
01:30 pm	30.1	31.5	4.65%
01:33 pm	30.3	31.9	5.28%
01:38 pm	30.5	31.8	4.26%
01:42 pm	30.6	31.9	4.25%
01:50 pm	31.2	32.9	5.45%
02:10 pm	30.1	31.8	5.65%
02:13 pm	30.7	32.1	4.56%
03:15 pm	30.2	30.9	2.32%
03:20 pm	30.4	31.2	2.63%
03:30 pm	30.8	32.1	4.22%

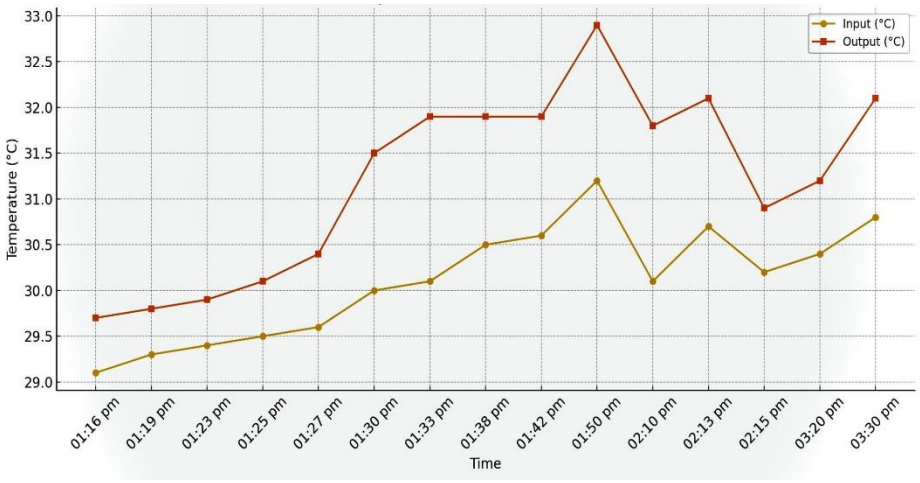


Figure 5.1 : Temperature Variation VS Time

5.2 Advantage

Using solar energy, rather than other sources of energies like fossil fuels and gasses helps us to reduce our dependence on the harmful energy resources. Therefore, solar water,

heaters are 50% more efficient than other water heating system. They reduce greenhouse gases, improve the quality of the environment, and save our money. Cost of solar water, heating systems are usually expensive compare to other water heaters but it saves the users money in the long run. Its hot water will be essentially free after a few years (4-6 years) usage. There are many advantages with the solar water heaters which are explained in detail as:

Environmental

Solar water, heaters do not pollute, the environment. It help to avoid CO2, NO, SO2 and wastes which basically created by the local utilities when generate power or when burning the fuel to heat domestic water. The replacement of solar water heaters with other water heaters can avoid around 50 Tons of CO2 emissions which are generally produced by electric, water heaters within around 20 years.

Economic

With using a solar water, heating system the user can save 50% to 85% annually on his utility bills over the cost of electric, water heater. The cost of hot water is relevant to the intensity of solar radiation falling on the system, and is varying from region to region.

Long-term

After few years in which the system is used by the users, it generates free hot water which saves users money, and there would be no worries from future fuel shortages and price, increases. These systems are good solutions to reduce the foreign oils usages. It helps to be independent. A home which already has a solar water, heater, is good for resale.

- There are many advantages of our project because of its accuracy. Some of the advantages are pointed out below:
- Solar water heating is free process.
- Water heating with a solar is healthy
- Solar cookers make no noise.
- Solar water heating system is portable.
- Power cuts is not an issue
- Cost-effectiveness
- Reduce energy waste

- No Oil consumption.
- Simple Construction
- Easy to operation

5.3 Disadvantages

- Water will be heat slowly.
- Foggy Weather it will not able to produce heat.
- It is a demo project so it is use in small scale.

5.4 Application

- Some of the application areas of the project have been pointed out below:
- It can be used for Water heating
- Heating water for commercial purposes.
- Water Purification

5.5 Discussion

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficient.

CHAPTER 6

CONCLUSION

6.1 Conclusion

It was design and fabricate a solar water heater. This project was completed by following the research and theoretical knowledge. A reliable and lowcost solar water heater according to the local needs was developed as stated in the objectives. It involved a great research knowledge while designing the components and management skills. All the parts were manufactured and assembled to achieve the desired results by using the local materials and technologies. As stated earlier that project was designed and completed with local needs, it helps a lot to reduce the cost of project. It reduces the time and cost of the materials and manufacturing. It was a good project which involved five people. It was a great privilege for us to work in this project and complete it within time. Cost effectiveness was the main objective which was fulfilled throughout the project. We learn to work more in less time. The highest heating was observed at 01:00 PM, as both the outlet temperature and inlet temperature were the highest at this time.12:00 PM and 01:00 PM—These two times had the highest temperature rise (20°C), resulting in the highest heating efficiency. This data suggests that the system worked most effectively between 12:00 PM and 1:00 PM.

6.2 Limitations:

- Limited Power Output: The 10W solar panel provides only a small amount of power, limiting the system's scalability or ability to power larger loads.
- Weather Dependency: The system performance heavily depends on sunlight availability. Cloudy or rainy weather reduces efficiency significantly.
- Manual Controls: If the system lacks automation or sensors, manual control may be required for operation and adjustments.
- Basic Insulation and Material Constraints: The use of low-cost materials may affect durability, especially in outdoor or long-term use.
- No Energy Storage (If applicable): If no battery is included, the system cannot store excess energy for night-time or low-sunlight operation.

6.3 Future Recommendations:

- Upgrade to Higher Wattage Panel: Use a 20W or 50W solar panel to increase power availability and allow for more components or extended use.
- Add Battery Storage: Integrate a rechargeable battery system (e.g., Li-ion or Lead-Acid) to store energy and allow operation during low sunlight.
- Implement Automation: Use microcontrollers (e.g., Arduino or ESP32) with sensors (temperature, flow, light) for smart, automatic operation and efficiency tracking.
- Improve Efficiency: Use MPPT (Maximum Power Point Tracking) charge controllers to optimize energy harvest from the solar panel.
- Compact and Durable Design: Enclose the system in a weatherproof, durable case for real-world application and longevity.
- Scalability: Design a modular version of the system that can be expanded or linked with additional units for increased capacity.
- Data Logging and Monitoring: Add Io T capabilities for remote monitoring, performance analysis, and maintenance tracking.

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