DESIGN AND PERFORMANCE ANALYSIS OF EVAPORATIVE COOLING SYSTEM

A Project

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September 2025

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In partial fulfillment of the requirement for the award of the degree

of

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

September 2025

DESIGN AND PERFORMANCE ANALYSIS OF EVAPORATIVE COOLING SYSTEM

We thus certify that the undergraduate thesis work described in this thesis was completed by us under the guidance of Md. Faruque Hossain, Lecturer, Sonargaon University (SU) Department of Mechanical Engineering, and that this report has not been submitted in whole or in part to any other university for another degree, award, or other reason. We hereby certify that Sonargaon University's (SU) Department of Mechanical Engineering is the sole owner of all copyrights to this practicum report. It is strictly forbidden to reproduce or use in any way without Sonargaon University's (SU) explicit approval.

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ACKNOWLEDGEMENT

First, we started in the name of almighty Allah. This thesis is accomplished under the supervision of Name, Designation, Department of Mechanical, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestion, constructive criticism and endless patience through the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

The authors are also grateful to Prof. Md. Mostofa Hossain, Head of the Department of Mechanical Engineering and all respect teachers of the Mechanical Engineering Department for their co-operation and significant help for completing the thesis work successfully.

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ABSTRACT

In this project, we developed an Evaporative Cooling System that provides a simple, affordable, and eco-friendly way to cool air. Instead of relying on expensive and power-hungry air conditioners, our system uses the natural process of water evaporation. Hot outside air is drawn through a wet cooling pad, where the water absorbs heat as it evaporates, resulting in cooler and more refreshing air. To keep the system running smoothly, we included a water pump, reservoir, distributor, and exhaust fan, along with a soil moisture sensor that helps maintain the right water level and prevents the pump from running dry. The system is powered through an SMPS with relay control for safety and automation. This design significantly reduces electricity consumption, saves water, and offers a sustainable solution for cooling homes, offices, greenhouses, or workshops. Our goal is to provide comfort while protecting both the environment and resources.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the past few decades, the demand for energy in various parts of the world for cooling buildings has increased, raising concerns about depleting energy resources and contributing to global warming. For hot climate regions, energy demand ranges from 40 to 50 % of the total energy consumed, with the largest proportion of energy consumed in buildings going to heating and cooling systems, in addition to population growth and technological progress in the world in recent times. In addition to the higher life requirements and longer lifespan of occupants inside buildings, all this has led to an increased need to remove heat loads, especially in higher temperatures and tropical climates. This requires finding ways to improve cooling system performance and reduce energy consumption.

One of the techniques used for cooling is evaporative cooling technology, as this technology is considered one of the most environmentally friendly methods because it consumes less energy and its performance increases as the temperature increases and the humidity decreases. Evaporative cooling is used in many applications such as residential buildings, as well as in industrial, commercial and agricultural buildings. Evaporative cooling systems are classified into direct evaporative cooling, in this type the working fluids consisting of water and air are in direct contact.

The second type is the indirect evaporative cooling system. In this type, the working fluids are separated by plates. While the third type is a combined evaporative cooling system between direct and indirect. Evaporative coolers are used in many domestic, industrial and commercial applications. They are also used to cool the air inside buildings, factories, and greenhouses. They work either as individual coolers or as complementary units to other cooling systems. They are also used in evaporative condensers and cooling towers. In general, evaporative cooling consists of a porous material that is fed with water, where dry and hot air is drawn over the porous material and as a result the water evaporates in the air

and its moisture increases and at the same time the air temperature decreases. The basic principle of controlling the evaporative cooling process is the transfer of heat and mass through the evaporation of water, as this process depends on the transformation of sensible heat into latent heat by means of a change in temperature. Sensible heat is heat associated with a change in temperature. While changes in sensible heat affect temperature, it does not change the physical state of water. Conversely, latent heat transfer only changes the physical state of a substance by evaporation or condensation. As water evaporates, it changes from liquid to vapor. This change of phase requires latent heat to be absorbed from the surrounding air and the remaining liquid water. As a result, the air temperature decreases and the relative humidity increases. The maximum cooling that can be achieved is a reduction in air temperature to the wet-bulb temperature at which point the air would be completely saturated.

In the normal evaporative cooling system, the surrounding air is used directly, and therefore its ability to retain moisture is dependent on the external conditions (temperature and moisture content), and therefore the cooling efficiency is low at high humidity, and in order to improve the performance of the evaporative cooling system and increase its efficiency, the air is dried pre. The evaporative cooling process in which the air is dried before it is used is called enhanced evaporative cooling.

1.2 Evaporator cooling technology

Evaporator cooling is based on the principle that water absorbs heat so that the liquid state turns into steam, and thus the sensible heat is transformed into latent heat. One of the most important benefits of evaporative cooling is its low cost, good energy savings, improve indoor air quality and also reduces carbon dioxide emissions from power plants. Many researchers have been conducted to study evaporator cooling systems. Velasco et al. developed a ceramic evaporator cooling system, which works as a semi-indirect cooler, where the water to be cooled is passed into a cooling tower made of ceramic tubes. This type of system allows the indoor air to be recalculated as a temperature drop ranging from 5-12 °C was obtained. Jain developed a two-stage evaporative cooling system to improve the efficiency of the evaporative cooling system at high humidity and reduce air temperature. The results showed an increase in cooling efficiency by (100 to 110) %. El-Dessouky et al. improved performance of a two-stage evaporator cooling system Where the operating

system was considered a function of the thickness of the package and the rate of water flow as a function of the direct and indirect evaporative cooling unit. Shaheen and Hmmadi conducted a theoretical and experimental study for a hybrid system consisting of a conventional refrigeration unit and an evaporative air cooler. This research aims to improve the performance of the evaporative air cooler, reduce the moisture content of the air leaving the system, and produce fresh water. The effect of several parameters such as inlet temperature, evaporator temperature, relative humidity and wetted pad thickness was studied. The results showed that the outlet temperature decreased by 1-3, and the amount of fresh water also increased when the relative humidity increased, the coil temperature decreased, and the front air velocity decreased. The results also showed that the effectiveness increases with the increase in the thickness of the pad.

1.3 Classification of Evaporator Cooling Systems

Depending on the type of heat and mass transfer process between water and air. Evaporative coolers could be classified into:

- Direct evaporative coolers, in which the working fluids (water and air) are in direct contact.
- Indirect evaporative coolers, where a surface/plate separates between the working fluids.
- Combined system of direct and indirect evaporative coolers and/or with other cooling cycles.

1.4 Problem Statement

In today's world, the demand for cooling is rapidly increasing due to rising global temperatures, population growth, and longer indoor living hours. Conventional air conditioning systems, although effective, consume excessive electricity, raise operational costs, and contribute to environmental challenges such as global warming. This makes them less suitable for regions with limited resources and high energy costs. People need a cooling solution that is both affordable and eco-friendly. The challenge is to design a system that reduces energy consumption while still providing comfortable indoor conditions. Our project addresses this by developing a smart and sustainable evaporative cooling system.

1.5 Objectives

The objectives of this project are

- To design an Evaporative Cooling System.
- To analyze the performance of fabricated cooling system.

1.6 Methodology

Our used methodology for the project:

- Designing the Evaporative Cooling System based on the principle of water evaporation. Preparing a block diagram and circuit diagram to identify all major components such as pump, fan, reservoir, evaporative pad, sensors, SMPS, and relay control.
- Selecting components including water pump, exhaust fan, evaporative pad, water reservoir, SMPS, relay, and sensors (temperature, humidity, and water level).
- Building the circuit on a breadboard or PCB. Connecting the pump, fan, sensors, and control unit as per the designed circuit. Testing individual modules and verifying the cooling efficiency.

1.7 Work Flow Diagram

The development of the Evaporative Cooling System follows a systematic methodology. First, a detailed study is carried out on the principle of evaporative cooling and existing technologies. Next, the design stage involves preparing block and circuit diagrams to plan the system. After that, necessary components are collected, including pump, fan, evaporative pad, sensors, and power supply. In the assembling phase, all components are interconnected and mounted to form the cooling unit, integrating both electrical and mechanical parts. Finally, the complete project is tested under different conditions to evaluate cooling efficiency, water consumption, and overall system performance.

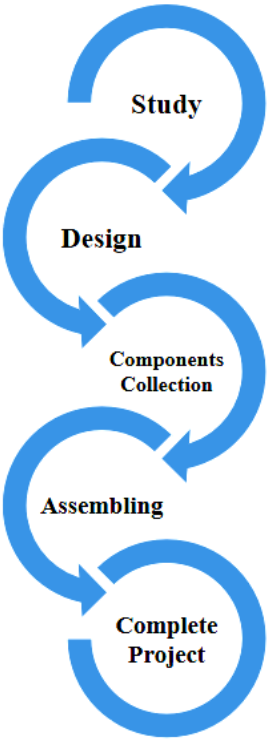


Figure 1.1: Work Flow Chart

1.8 Report Overview

This project book consists of Six chapter. The first chapter contains the statement of the Introduction, Evaporator Cooling System, Classification of Evaporator Cooling System Problem Statement, Work Flow Diagram, objectives of the study and Methodology. Chapter two contains system Literature Review details. Chapter three System Architecture, discussed in Block Diagram, Circuit Diagram, Working principle and Cost analysis. Chapter Four describes the hardware implementation with component details and the software which we have used for our work. Chapter Five deals with the result Analysis, shows the complete prototype, Advantage, Application and Limitation of the project that we have built. In the final chapter, we have discussed the, Future Scope, conclusion of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter we discuss our system overview. In this paper we are also work about **Evaporator** Cooling System. In below section we will describe some previous literature review. From previous literature we gather more knowledge to build this project and we successfully made it.

2.2 Literature Review

Somchai jiajitsawat [1] has fabricated and tested a portable hybrid thermoelectric-direct evaporative air cooling system based on a commercially portable direct evaporative air cooler integrated with a thermoelectric refrigeration system. In this hybrid thermoelectric direct evaporative air cooling system, 12 thermoelectric modules TEC1-12708 are used to cool water by stacking their cool side into layers on one wall of the aluminum container and the hot side on the rectangular fin heat exchanger. This cooled water is then used for a direct evaporative cooling system. This direct evaporative cooling system is used as a main air-cooling system by inducing the hot ambient air in direct contact with the working fluid (water). The testing results show that under the fan operation, the system is unable to cool the inlet air temperature (or 0% cooling effectiveness) When the DEAC system is active, the cooling performance of the prototype increases by 20% and is up to 30% with higher fan speed (or 1.7 C of air temperature drop). The results of TE installation shows that it can improve the cooling performance of the DEAC system by 10% and is up to 20% with higher fan speed (or 2.6 °C of air temperature decrease). Therefore, the concept of applying TEs to cool the water temperature in the container seems to be reliable not only for its additional cooling capacity but also for contributing more convenience to a portable DEAC system in the market. However, due to the low COP of 0.06, the heat exchanger at the hot ends of TE should be redesigned carefully in order to improve the cooling performance of the TE system.

Bogdan Porumba et.al [2] discussed a review of IEC (indirect evaporative cooling technology). Indirect evaporative cooling is an emerging technology that has promising potential to improve air conditioning. The review presents theoretical and practical aspects related to the IEC's development including theory, construction principles, flow schemes, working conditions, and parameters of performance. From a geometric perspective, there are constructions based on horizontal or vertical plates and also horizontal tubes. The different flow schemes let you use outside and inside air as your primary or secondary supply of fresh air. It is a very common practice to regenerate it, which involves recirculating part of the cooled primary supply as secondary. The R-IEC equates to the ratio between Primary (0…100%), Fresh Air, and Secondary.

N. Beemkumar et.al [3] investigated an air cooler with thermal storage, which can be used as an AC backup system when in a room where the AC unit is turned off or not working properly or during power outages. The units are placed inside the air-conditioned room near the main AC and will keep cool until it's needed again. During a normal time of A/C operation, the PCM in the heat exchanger changes from liquid to solid and stores cold energy as latent heat of fusion. In case of power failure, the mobile air cooler with PCM storage uses only the fan operation from DG set for circulating chilled air through it. This cool air is concentrated in the area where occupants are present and cooling can be achieved locally. The phase change material has a phase change temperature of 25°C to 26°C, which makes it appropriate for this application. The use of this air cooler is ideal for restaurants and shopping complexes, where diesel generators cannot run their AC units.

Franck Lucasa et.al [4] developed a method to evaluate the energy performance of buildings cooled by room air conditioners, like split AC systems. These types of small ACs are often installed without proper study of their building envelope's performance just because of their low cost and small size. This isn't a question of whether or not the system is maintained, but rather if it is done according to regulations. Some tradesmen sometimes neglect to comply with these rules and regulations. If maintenance is not carried out properly then eventually the systems will be compromised and energy performance will suffer. This article provides an overview of a practical, global approach to diagnosing the performance of existing small air- conditioning installations in buildings on Reunion Island. One goal for this tropical island is to become self-sufficient with electricity. This approach uses a numerical tool to help you determine the best system for your building and it relies on dynamic simulations

of buildings equipped with AC. The simulations, which take account of all aspects including the envelope, as well as users' practices, are based on kernel calculation Energy. In order to help make better decisions, they also take into account climatic conditions and provide an estimate of the annual electricity consumption related to cooling a zone. This global analysis helps to qualify them by assigning an energy label.

T. Wessapan et.al [5] conducted research on the portability of an air conditioning-heat pump unit that uses a helical coil heat exchanger making use of both heating and cooling systems to maximize energy utilization by using the waste heat recovery from an air conditioner, for warming water. In recent years, there have been some scholars who study the use of a helical heat exchanger for recovering waste heat from domestic water-cooled air conditioners. However, there is no evidence that the helical heat exchanger has ever been used with a portable air-conditioning system to improve the cooling performance of a portable A/C unit and enhance its heat recovery performance. The portable air conditioning heat pump unit was fabricated in the lab and then tested at water flow rates ranging between 0.5 - 2 liters per minute. In the experiments at full load conditions, they measured and evaluated cooling performance, heat recovery, and power consumption for different water flow rates.

Vahid Khalajzadeh et.al [6] conducted a study in which researchers conducted a case in Iran's capital city of Tehran. The IEC faced restrictions during certain summer days- so the team chose it as their geographical location to examine the thermal performance of decentralization and centralization systems. Since centralized heating is not always sufficient for comfort conditions, they decided to explore different systems that would provide better results. A temperate, dry climate is found in Tehran. The wet bulb temperature is less than 23℃ and the dry-bulb temperature goes down to less than 40 ℃. Aluminum fins with staggered copper tubes that cool air for a small dwelling air conditioner, where water and air mass flow rate is chosen to be suitable for the type of unit being used. Other CCU specifications are presented. An indirect evaporative heat exchanger is used to provide a cooling performance and increase the efficiency of a hybrid system, which has an air temperature at the exit of each section about 8–11◦ C lower than that inlet. Thus, the ambient air is able to enter IEC with a lower wet-bulb temperature. In this case, the maximum and minimum heat reduction in the GCC are 4.5 kJ/s and 3.1 kJ/s, respectively; while there is maximum cooling effectiveness of 0.73 and minimum cooling effectiveness of 0.59. This process of pre-cooling helps the IEC to achieve higher performance. By

integrating an additional cooling device into the unit, its total cooling effectiveness increases significantly. The proposed system's effectiveness is greater than unity, which means that this system can decrease air temperatures below wet-bulb temperature.

Takahiko Miyazaki et. al. [7] have developed a building integrated photovoltaic-thermal (BIPVT) setup, with the goal of developing a passive cooling device that can effectively minimize the cooling load on central air conditioners in hot and humid weather. The authors recommended using a solar chimney and a dew point evaporative cooler to incorporate a passive cooling system into a structure. The cooling performance of the system with a modified design has been simulated in this study. Evaporative cooling is a way of cooling outdoor air before supplying it to an area. Both active and passive systems can benefit from evaporative cooling. Evaporative cooling for passive systems is a field that has been relatively unexplored, and the technology to combine it with building structures is still in the works. The passive system, which consisted of a south wall collector and a roof duct with an evaporative cooling surface, was shown to control temperature fluctuations in the room, keeping it around 30°C during the summer while the ambient temperature reached 42°C at its highest. Chungloo and Limmeechokchai assessed the performance of a solar chimney with a water- sprayed roof, and the results showed that when the two passive measures were combined, the room air temperature dropped by 2.0–6.2 degrees Celsius when compared to the ambient temperature. Maerefat and Haghighi developed a system with a solar chimney and an evaporative cooling chamber by employing a mathematical model to investigate the effects of geometrical dimensions as well as ambient conditions on cooling effectiveness. The results showed that the proposed system could improve indoor conditions with a low solar intensity of 200W/m2 and a high ambient temperature of 40°C. They found that the system produced suitable interior air conditions at a high ambient temperature and relative humidity of less than 50%, but that the relative humidity of the ambient air had a significant effect on room air temperature. Passive cooling is a cooling technique that does not rely on active mechanical equipment, such as pumps and fans, but instead depends on buoyant air movement to provide cooling. Solar chimneys, Trombe walls, and double facades are all examples of devices that rely on the stack effect to stimulate air movement, and the increased natural ventilation provided by those devices will provide cooling. In a hot and humid climate, natural ventilation on the other hand may compromise building thermal comfort, as the temperature and humidity of outdoor air during the day are significantly higher than that of an air-conditioned room. During the summer months, it is

not uncommon for outside air temperatures in Japan to exceed 25 degrees Celsius throughout the night.

Jakkula Rajesh et.al.[8] did a detailed study of the vapor compression refrigeration cycle, as well as the classification of condensers and evaporators in refrigeration and air conditioning systems. A portable air conditioner's coefficient of performance (COP) utilizing R22 was calculated and found to be 8.96

Shahi Satyam et.al [9] researched and developed a portable air conditioner system that meets the users' needs at the lowest possible cost, and the manufacturing and maintenance costs are extremely low. It has comparable cooling power to a wall air conditioner, is easily transportable, and can be moved anywhere. It is small and so would be suitable for our bedroom, living room, and kitchen. It is completely non-toxic.

Garud Akhilesh Ravindra et. al [10] developed a portable A.C. that is extremely simple to install, and it is generally cheaper to implement additional energy-saving measures when retrofitting work is already being performed on a building than when the hospital is in normal operation. They eliminated the need for a centralized air conditioning system.

W. N. Fakhira [11] developed a thermoelectric air cooler that is feasible and marketable. The thermoelectric air cooler is based on a Peltier for cooling, and it fulfills the basic air conditioner functions. The thermoelectric air coolers were tested on their functions and reliability of construction. Human factors taught us that people can be uncomfortable because of several factors. Temperature is one of them, as we all know that certain countries, particularly those with a tropical climate, such as South East Asia, have a hot temperature climate. Because of this, a thermoelectric air cooler is one of the most important things that can help a student feel comfortable. This thermoelectric air cooler is a good deal for students because of its shape, which makes it easy for them to carry it everywhere. Some students have limited space for air conditioning, so this smart thermoelectric air cooler can be fitted in a study space near the user to free up that space for an air conditioner. Because it is lightweight and portable, the thermoelectric air coolers could be relocated and set up quicker.

Nilesh Ambaji Jadhav [12] noticed the problem of global warming as the conventional air conditioning system gives out Chloro-Fluoro Carbon resulting in depletion of the Ozone layer due to global warming. Nowadays there is a day's power crisis. So, importance should be given to power saving and energy conservation. After noticing all the problems like this he developed a 360° air cooler and heater to reduce the consumption of energy. 360° air cooler and heater is a device used to cool or heat the air according to the requirement of the user. A conventional air conditioning system uses three to five times electricity as compared to the 360° air cooler and heater which results in the emission of a considerable amount of heat resulting in global warming. In this project 360˚ air cooler cum heater will be designed, developed, and fabricated for low operational and overall cost.

Vignesh Ravi et. al [13] has Designed and Fabricated the MINI AIR COOLER in which the cooling of air by using cold water or any other refrigerant is circulated in the copper tube for the purpose of reducing the heat in the surrounding environment, where it is of great importance in widely distributed villages with little or no rural electrification and also in the urban areas where power shortage is often in practice. They identified the problem of poor people and the power shortage problem and worked on this project.

2.3 Summary

Our project focuses on developing an Evaporative Cooling System as an eco-friendly and low-cost alternative to conventional air conditioning. By combining pump, fan, reservoir, and sensors, we created an automated system that delivers cool, refreshing air with reduced energy use. Teamwork turned this concept into a practical, sustainable solution.

CHAPTER 3

SYSTEM ARCHITECTURE

3.1 Introduction

The project objectives, methods, literature evaluation, and other details were all clarified in the preceding chapter. The block diagram, circuit diagram, working principle, and cost analysis will all be covered in this chapter.

3.2 Proposed System Design

This evaporator cooling system is so effective and safe process. It is mainly used in home, hospital, factory and industrial area. After it used, we reduce the cost of money to cool air. That's way we get good efficiency. Where very cost effective to buy air-condition but our system is reducing the cost. This machine is very easy to use and it works very effectively. A working procedure relevant image is added below –

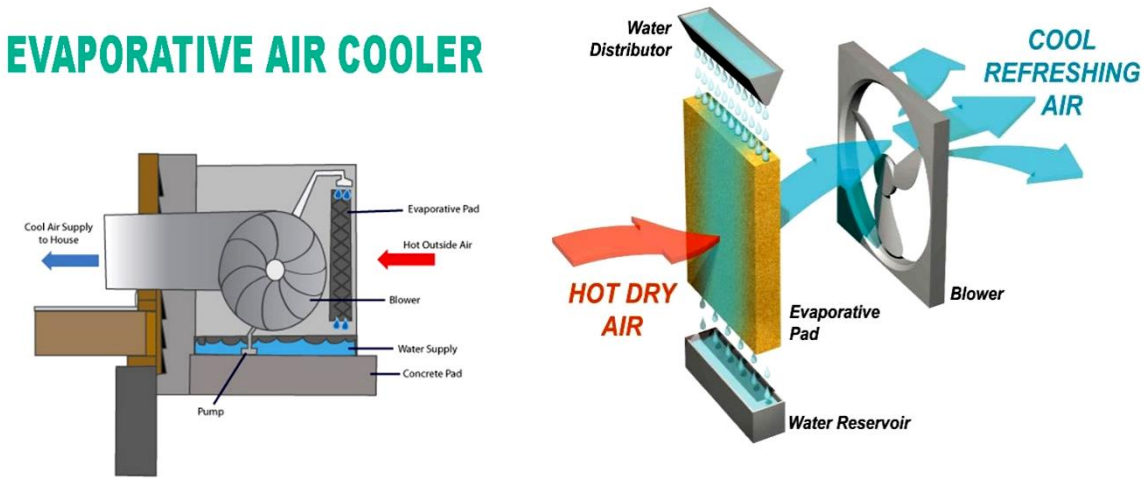


Figure 3.1: Proposed Design of Evaporator Cooling System

3.3 Principle of Evaporative Cooling

When trying to understand evaporative cooling, it may be the best to think of air as being like a sponge or cooling pads, in that regard, air has an ability to absorb moisture that it come in contact with. The amount of moisture that the air will absorb depends on the state of air and the temperature of the air. If the air is warm and contains only a small amount of moisture, it will more radially absorb moisture. As air cools, it volumes decreases, and with it, its ability to absorb moisture decreases. Cooling through evaporation is a natural occurrence and the most common we all experiences is perspiration, or sweat as perspiration evaporates, it absorbs the heat to cool our body. It is a heat and mass transfer process that requires water for evaporation for the coolness in which heat is transferred from air to water and simultaneously the temperature of air decreases.

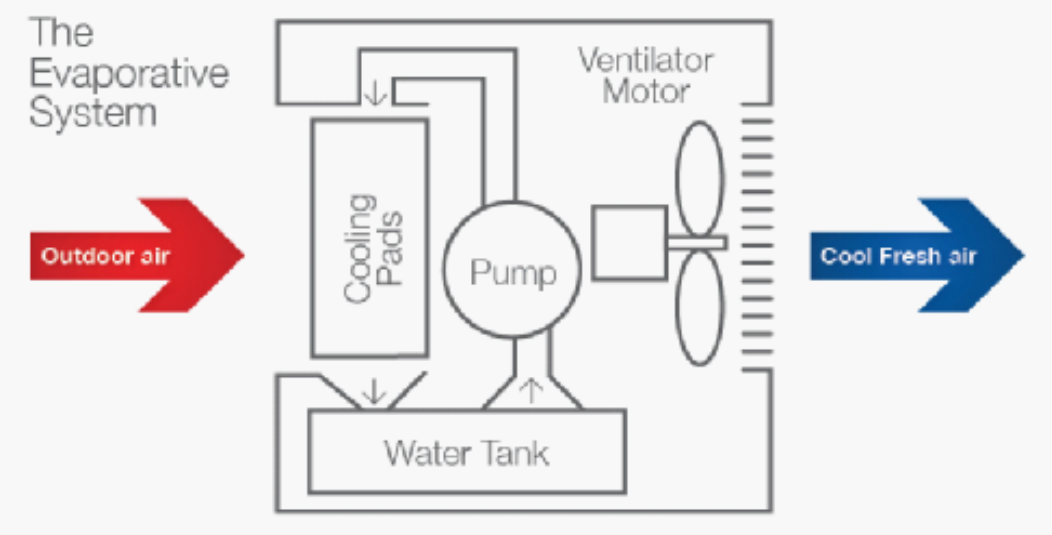


Figure 3.2: Working Principle of Evaporator Cooling System

The principle underlying evaporative cooling is the facts that water must have heat applied to it to change from liquid to vapor. When evaporation occurs, this heat is taken from the water that remains in the liquid state, resulting in a cooler liquid. The evaporative coolers are classified as:

- Direct Evaporative [Working fluid as water and air in direct contact]
- Indirect Evaporative cooler [Surface plates separates the working fluid].
- Combination of both the Direct and Evaporative Coolers [With different cooling cycles]

3.4 Block Diagram

Here is the block diagram of the Evaporator cooling System with all the essential components. All of the components are shown in below as a block in this diagram.

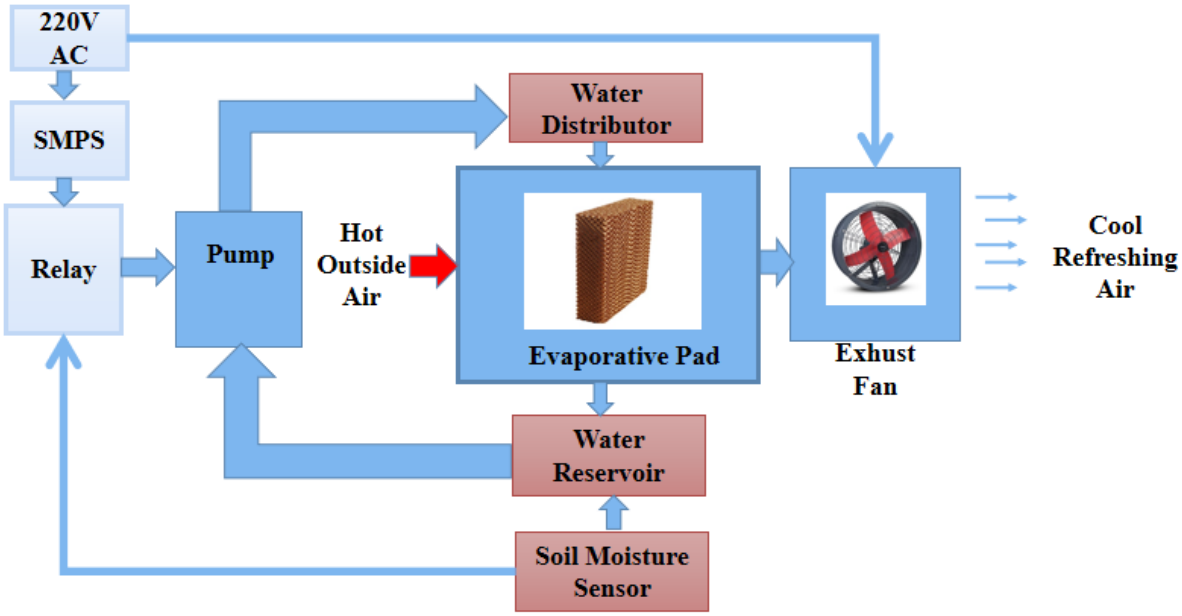


Figure 3.3: Block Diagram of Our Project

3.5 Working principle

The Evaporative Cooling System works on the natural principle of heat and mass transfer through water evaporation. In this system, hot ambient air is drawn into the unit by an exhaust fan. Before entering the living space, the air passes through an evaporative cooling pad, which is continuously kept moist by a circulating water pump. When the hot air flows over the wet surface of the pad, the water begins to evaporate. During evaporation, latent heat is absorbed from the air, causing its temperature to drop while simultaneously increasing humidity. This cooled and refreshed air is then supplied to the room or designated area, creating a comfortable environment. Sensor monitor water level to ensure smooth and automated operation. Thus, the system provides a sustainable, low-cost, and eco-friendly alternative to conventional air conditioning.

3.6 Cost Analysis

Table 1: List of Component with Price

Sl.no	Particulars	Specification	Qty.	Unit Price (Taka)	Total Price (Taka)
1	SMPS	5V 7A	1	600	600
2	Evaporator pad		1	1200	1200
3	Pump Motor	5V DC	1	200	200
4	Exhaust Fan	AC 220V	1	2000	2000
5	Soil Moisture Sensor		1	250	250
6	Relay		1	200	200
7	Temperature meter	Digital	1	300	300
8	Others				2000
				Total	6750/=

CHAPTER 4

HARDWARE & SOFTWARE ANALYSIS

4.1 Introduction

In this section, we will discuss elaborately about “Evaporator Cooling System” and the component description, features, working procedure of our all equipment. The system hardware fabricates composed of power unit, sensor unit and many more related components.

4.2 Hardware & Software

Hardware

- SMPS
- Soil Moisture Sensor
- Relay
- Pump Motor
- Evaporator Pad
- Exhaust Fan
- Temperature Meter

Software

- Easy EDA

4.3 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. A hypothetical ideal

switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.



Figure 4.1: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or

power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

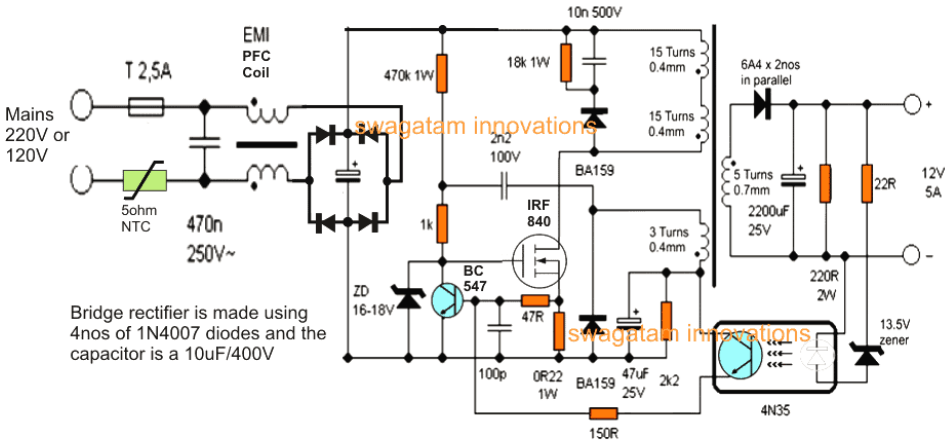


Figure 4.2: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) per-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electro technical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer.

There are different circuit configurations known as typologies, each having unique characteristics, advantages and modes of operation, which determines how the input power is transferred to the output. Most of the commonly used typologies such as fly-back, push-

pull, half bridge and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps. The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits. There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output.

Switch Mode Power Supply

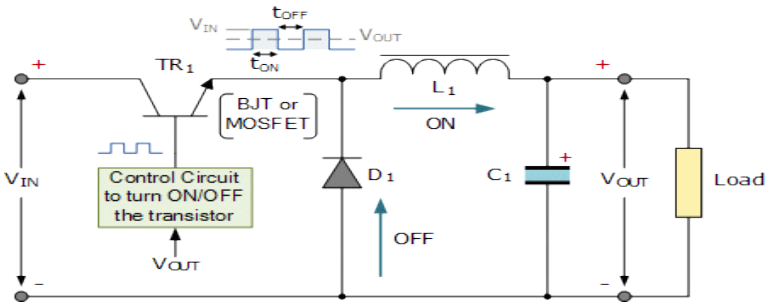


Figure 4.3: SMPS Circuit Connection

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabilizer circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this:

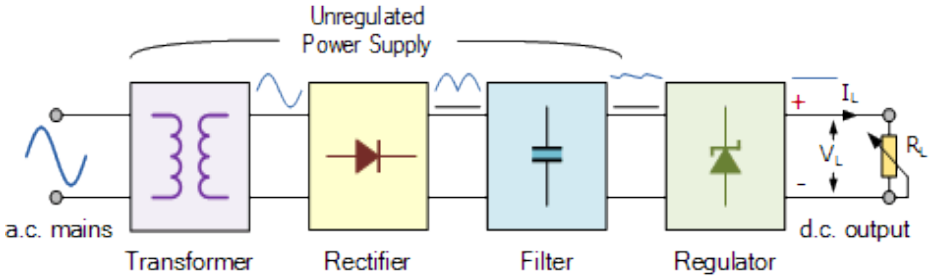


Figure 4.4: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

4.4 Soil Moisture Sensor

This soil moisture sensor module is used to detect the moisture of the soil. It measures the volumetric content of water inside the soil and gives us the moisture level as output. The module has both digital and analog outputs and a potentiometer to adjust the threshold level.

Table 2: Pin Description of Soil Moisture Sensor

Pin Name	Description
VCC	The VCC pin powers the module, typically with +5V
GND	Power Supply Ground
DO	Digital Out Pin for Digital Output.
AO	Analog Out Pin for Analog Output

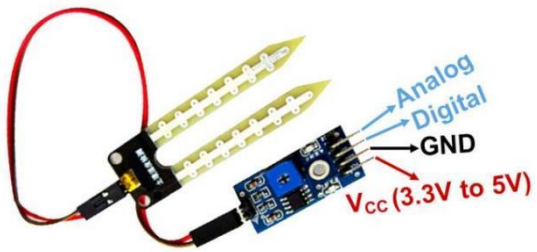


Figure 4.5: Soil Moisture Sensor

Moisture Sensor Module Features & Specifications

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on infrared radiation from fire flame falling on the sensor
- LED's indicating output and power
- PCB Size: 3.2cm x 1.4cm
- LM393 based design
- Easy to use with Micro-controllers or even with normal Digital/Analog IC

4.5 Pump Motor

This is a low cost, small size Submersible Pump Motor which can be operated from a 2.5 ~ 6V power supply. It can take up to 120 litters per hour with very low current consumption of 220mA. Just connect tube pipe to the motor outlet, submerge it in water and power it. Make sure that the water level is always higher than the motor. Dry run may damage the motor due to heating and it will also produce noise.



Figure 4.6: Pump Motor

Features

- Operating Current: 130 ~ 220mA
- Flow Rate: 80 ~ 120 L/H
- Maximum Lift: 40 ~ 110 mm
- Continuous Working Life: 500 hours
- Driving Mode: DC, Magnetic Driving
- Material: Engineering Plastic
- Outlet Outside Diameter: 7.5 mm
- Outlet Inside Diameter: 5 mm

4.6 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.



Figure 4.7: Relay

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not be able to transition the contacts. Magnetic latching relays can have either single or dual coils. On a single coil device, the relay will operate in one direction when power is applied with one polarity, and will reset when the polarity is reversed. On a dual coil device, when polarized voltage is applied to the reset coil the contacts will transition. AC controlled magnetic latch relays have single coils that employ steering diodes to differentiate between operate and reset commands. The relay module is the one in the figure below.

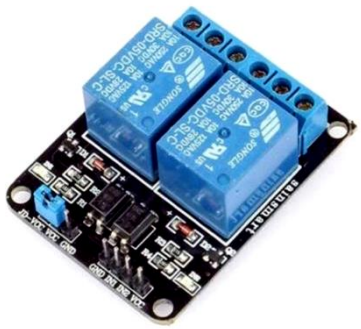


Figure 4.8: Relay Module.

This module has two channels (those blue cubes). There are other varieties with one, four and eight channels.

Main's voltage connections.

In relation to mains voltage, relays have 3 possible connections:

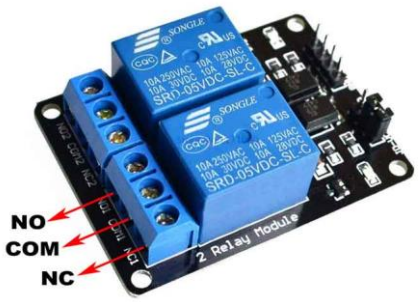


Figure 4.9: Main's voltage connections.

COM: common pin

NO (Normally Open): there is no contact between the common pin and the normally open pin. So, when you trigger the relay, it connects to the COM pin and supply is provided to a load

NC (Normally Closed): there is contact between the common pin and the normally closed pin. There is always connection between the COM and NC pins, even when the relay is turned off. When you trigger the relay, the circuit is opened and there is no supply provided to a load.



Figure 4.10: Voltage Connections

Pin wiring

The connections between the relay module and the Arduino are really simple:

GND: goes to ground

IN: controls the first relay (it will be connected to an Arduino digital pin)

IN2: controls the second relay (it should be connected to an Arduino digital pin if you are using this second relay. Otherwise, you don't need to connect it)

VCC: goes to 5V

4.7 Exhaust / Cooling Fan

A fan is a powered machine used to create a flow of air. A fan consists of a rotating arrangement of vanes or blades, which act on the air. The rotating assembly of blades and hub is known as an impeller, rotor, or runner. Usually, it is contained within some form of housing, or case.



Figure 4.11: Cooling Fan

Feature

- Operation Humidity - 0%~95%
- Insulation Grade - According to IEC61858 Grade F
- Voltage V - 220/230
- Frequency Hz - 50/60
- Current - 0.12/0.10
- Power(W) - 19/14
- Speed(R/Min) - 2500/2700

4.8 Evaporator Pad

General Air 990-13 evaporator pad, sometimes called a humidifier/water filter, is an indispensable part of the humidifier. The pad soaks up water as it passes through the humidifier, and then circulates humidity into the air. This keeps your home or business nice and comfortable during the dry season. This pad is made of aluminum encased in a heavy wire frame, and is coated with a special absorbent material which evenly draws water across the pad, and increases the amount of humidity produced. While these pads work hard to provide clean and comfortable air, as time passes, pollutants and minerals build up on the pad and diminish performance. It's important to note that the pad cannot be cleaned, and must be replaced at least once a year to ensure superior performance and air quality.



Figure 4.12: Evaporator Pad

Distribution & Return System Features:

- High efficiency system
- Cover up to 80′ with one pump!
- Largest self-contained PVC return gutter on the market today
- Easy to install, one-piece PVC trough
- Closed top or open top feature for easy visibility and regulation of water supply
- Submersible pumps
- Simple shut down for seasonally affected environments
- Optional stainless-steel return gutter wall mount brackets

Pad Features

- Water is spread evenly over the pad surface as a film rather than droplets for uniform wetting
- 6” deep pads specially designed and coated for effective evaporation and maximum durability
- Pad surface dries quickly in absence of water to inhibit micro-organism growth
- Coated pads are tough and durable for repeated cleaning
- Improved life expectancy over standard pads
- Easy to install, remove, and replace pads

4.9 Digital 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. Attempts at standardized temperature measurement prior to the 17th century were crude at best. For instance in 170 AD, physician Claudius Galenus 18 mixed equal portions of ice and boiling water to create a "neutral" temperature standard. The modern scientific field has its origins in the works by Florentine scientists in the 1600s including Galileo constructing devices able to measure relative change in temperature, but subject also to confounding with atmospheric pressure changes.



Figure 4.13: 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

SOFTWARE

4.10 Easy EDA

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share-publicly and privately-and discuss schematics, simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.



Figure 4.14: Easy EDA Software Interface

Subscription-free membership is offered for public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge; but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third party tools.

CHAPTER 5

DISCUSSION & RESULT ANALYSIS

5.1 Project Output

After finally completing this project, we ran it & we observed the output of this project. We can see that it is working well as expected. After making our project we observe it very careful. It works as we desire. Our project give output perfectly and all equipment are work perfectly. We check how much it works and we get perfect output from this project.

- Finally, we have completed our project successfully & check our project its run accurately according to our objective.
- At first, we start our system.
- Following are The outputs of our project.
- The system successfully reduced inlet air temperature by 5–10°C depending on ambient conditions.
- Humidity of the outlet air increased, ensuring a more comfortable environment in hot and dry climates.
- Power consumption was significantly lower compared to conventional air conditioning systems.
- The automatic pump and fan control worked efficiently, preventing water wastage and dry-run conditions.
- Sensor accurately monitored water level, ensuring reliable operation.
- The system demonstrated stable performance with continuous water circulation and even cooling pad wetting.

Overall, the project proved effective as a low-cost, eco-friendly, and energy-efficient cooling solution.

5.2 Final Project



Figure 5.1 Hardware Base



Figure 5.2: Complete Project Prototype

5.3-1 Efficiency of Evaporative Cooling System

Water inlet temp, $T_1 = 35$ °C

Water outlet temp, $T_2 = 32$ °C

Dry point temp = 35 °C

Humidity = 85%

Wet bulb temp = 30 °C

Dew point = 27 °C

Formula:

$$\eta = \frac{\text{Range}}{(\text{Range} + \text{Approach})} \times 100\%$$

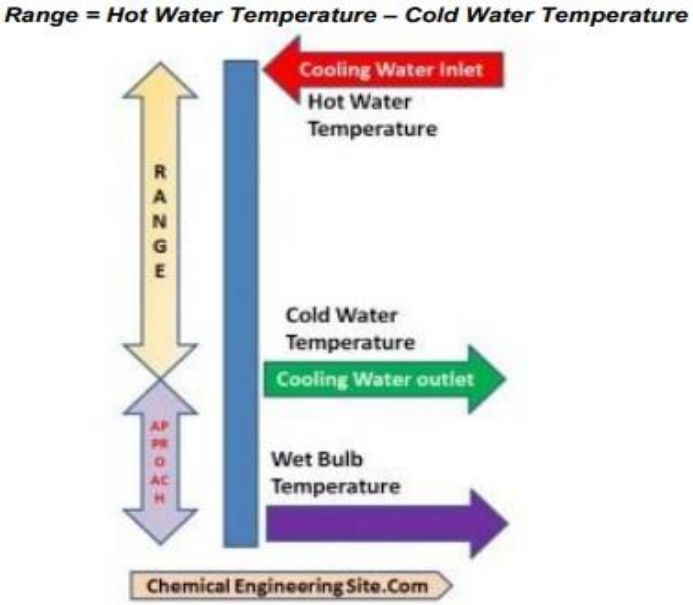
$$= \frac{T_1 - T_2}{T_1 - T_2 + T_2 - T_3} \times 100\%$$

Calculation

$$\eta = \frac{35 - 32}{35\text{-}30} \times 100\%$$

$$= 60\%$$

Diagram Notes



5.3 Advantages

There are certainly many advantages of our project and some of the major ones have been given below -

- Creates a comfortable and productive work environment.
- Good Indoor Air Quality.
- Energy-efficient ventilation and cooling solution.
- Environmentally friendly.
- Investment in this sustainable technique is often subsidized.
- No Oil consumption.
- Less skill technicians is sufficient to operate.
- Installation is simplified very much.
- Simple construction
- Ease of operation.

5.4 Limitations

It is a demo project so we found some limitation. In future we will work for reduce this kind of limitation. These limitations are -

- This project can now be only used for small scale purposes
- No energy backup.
- Needs continuous clean water supply.
- Limited cooling compared to conventional AC.

5.5 Applications

Some of the application areas of the project has been pointed out below-

- It can be used for Industrial work.
- It can be used in factories.
- It can be used for indoor purpose.
- It can be used in residential houses.
- It can be used in greenhouses

5.6 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.

The evaporative cooling system demonstrates a practical and sustainable approach to addressing the growing need for cooling solutions. Unlike traditional air conditioners, this project consumes significantly less power, making it cost-effective and environmentally friendly. During testing, the system effectively reduced the temperature of hot ambient air and created a more comfortable indoor atmosphere, particularly in dry and hot climates. However, its efficiency decreases in high-humidity environments, which limits universal applicability. The integration of sensors and automated control enhanced performance by ensuring optimal water use and safe operation. Overall, this project highlights the potential of eco-friendly cooling for everyday applications.

CHAPTER 6

CONCLUSION

6.1 Conclusion

The Evaporative Cooling System Project successfully proves that cooling can be achieved in an efficient, eco-friendly, and economical way. By applying the natural principle of water evaporation, the system reduces hot air temperature and delivers cool, refreshing air with very low electricity consumption compared to conventional air conditioners. This makes it especially suitable for regions with high temperatures and dry weather conditions. The use of sensors and a microcontroller ensures smart control of pump, fan, and water levels, making the system reliable and user-friendly. Testing showed positive outcomes, including a noticeable temperature drop, energy savings, and effective water circulation.

Although the system has some limitations, such as reduced efficiency in humid climates and the need for regular maintenance, its benefits outweigh the drawbacks. It can be widely applied in homes, greenhouses, factories, and small-scale commercial setups. Most importantly, this project emphasizes sustainable living by conserving energy and minimizing environmental impact. In conclusion, the evaporative cooling system is a promising solution for affordable and green cooling needs in today's world.

6.2 Future Scope

We are thinking about adding many features to our project in the future to get more desirable out comes. Some of the steps that we are thinking about taking are given below:

- In future development this project can be develop by more sensor.
- In future, I will try it to apply in real field.
- In Future develop add extra power system.
- In future integration with IoT for remote monitoring and control via smartphone apps.

REFERENCES

[1] Somchai Jiajitsawat, "A Portable Hybrid ThermoelectricDirect Evaporative Air Cooling System" Naresuan University Journal 2012.

[2] Bogdan Porumba, Paula Ungureşana, Lucian Fechete Tutunarua, Alexandru Şerbanb & Mugur Bălana, “A review of indirect evaporative cooling technology”, Energy Procedia 85,461 – 471,2016.

[3] N.Beemkumar, D.Yuvarajan, J.Jayaprabakar, Department of mechanical engineering, “Experimental Investigation on Air Cooler with Thermal Storage”, pg. 205-211 IEEE,2010

[4] Franck Lucasa, Pascal Ortegaa, Mathieu Davidb, Frantz Sinamab, Boris Brangeonb Fabien Picgirardc, “A Method To Evaluate Energy Performance Of Buildings Cooled By Room Air Conditioners”, The 7th International Conference On Applied Energy – Icae, pg. 1275 – 1283,2015

[5] T. Wessapan, T. Borirak, S. Teeksap , “A Development of a Portable Air Conditioning-Heat Pump Unit using Helical Coil Heat Exchanger ”,2nd International Conference on Computer Engineering and Technology, v5 186-189, Thailand 2010

[6] Vahid Khalajzadeh, Moien Farmahini-Farahani 1, Ghassem Heidarinejad, “A novel integrated system of ground heat exchanger and indirect evaporative cooler’’ Department of Mechanical Engineering, Tarbiat Modares University, P.O. Box 14115-143, Tehran, Iran 13 January 2012.

[7] Jakkula Rajesh, Suresh Akella, K. Sainath, “Portable Air Conditioner Design for Fabrication”, International Journal of Research in Engineering, Science and Management, Volume1, Issue-10, October-2018

[8] Takahiko Miyazaki, Atsushi Akisawaa, Isao Nikai, “The cooling performance of a building integrated evaporative cooling system driven by solar energy’’, Engineering Consultant, 5-7-12 Kiminomori-minami, Ooamishirasatomachi, Sanbugun, Chiba 299-3241, Japan 2011.

[9] Shahi Satyam, Sucheta Jagtap, Sanap Archana, Patil Swapnil, “Design and Development of Portable Air Conditioner”, International Journal for Research in Engineering Application & Management, Vol-02, Issue 07, Oct 2016

[10] Garud Akhilesh Ravindra, Dolas Nikhil Rajendra, Mahajan Sumit Prakash, Jadhav Rahul Devidas, Prof. Thakare Rakesh Balwant, “Review Study of Portable Air Conditioner”, International Journal of Engineering and management research, Volume-6, Issue-2, March-April 2016

[11] W N Fakhiraand, M K Fadzly, “Smart Portable Air Cooler Using Thermoelectric Peltier”, AIP Publishing,020150-1 to 5, 2019

[12] Nilesh Ambaji Jadhav,” DESIGN OF 360° AIR COOLER AND HEATER”, Journal of Emerging Technologies and Innovative Research, Volume 6, Issue 1,2019

[13] VIGNESH RAVI, A.SATHISHKUMAR, N.SIVA, R.RAVIKUMAR.” DESIGN AND FABRICATION OF MINI AIR COOLER, International Research Journal of Engineering and Technology (IRJET)”, Volume: 03 Issue: 12 Dec -2016