CHAPTER 1

Introduction

As the demand for electric vehicles (EVs) and energy storage systems continues to grow, ensuring optimal performance and longevity of the batteries becomes crucial. Battery cooling systems play a vital role in maintaining the temperature of batteries within safe operating limits,thereby enhancing their efficiency, reliability, and overall lifespan.

Battery cells generate heat during charging and discharging processes, and excessive heat canlead to various issues such as accelerated aging, reduced capacity, and even safety risks. A battery cooling system is designed to manage and dissipate this heat effectively, maintaining the battery's temperature within an optimal range.

1.1 Project Statement

In today’s day and age due to the heavy dependance of fossil fuels there has come a shortage of these fuels, due to this there is a demand in alternative ways to operate our vehicles, a new and sustainable fuel. Here electric vehicles come to play, EV’s are a new and upcoming mode of transportation in India and lately we have seen a demand in the purchasing of EV in India, the common mas has now got a affordable mean of purchasing a two wheeler EV which gives him more mileage than a IC engine two wheeler.

But with all good things there is always something negative, due to the sudden increase in thedemand of these two wheelers’ the manufacturers in a rush to produce them did few cost cuttingmeasures and did fewer test to make them road safe in India, this led to the scooters to have verybad quality parts, the most important the battery of the scooter. The batteries in these scootersdidn’t have any safety towards fire and heat management, hence in the extreme heat of India wesaw many of these EV’s batteries combusting out of he blue, some these where just parked thentoo the batteries burst into flame, this created a risk to life in buying and using EV two-wheeler. Many manufacturers like OKINAWA, JOY E-BIKES, ATHER, OLA, BAJA issued quick recallof some their models which they felt had an issue with the batteries thermal management system,after some research it was found that the vehicles with removable batteries never had propercooling system for the vehicle which was the main reason for the batteries to catch fire.

1.2 Objectives

After our group did a little brain storming and few nights spent doing research, we devised a planto do a project to solve this problem, we came up with the idea of a system that will be present inside the battery box (the arear in the scooter where the removable battery is placed) And assist in the cooling the battery, this project will be called LIQUID BATTERY COOLING SYSTEM. To successfully accomplish this project, we decided of some objectives to keep in mind when doing this project

- Temperature Regulation: The primary objective of a liquid battery cooling system is to regulate the temperature of the batteries within a specified range. Excessive heat can negatively impact battery performance, efficiency, and lifespan. Cooling helps maintain optimal operating temperatures and prevents overheating.
- Heat Dissipation: Liquid cooling systems are designed to efficiently dissipate the heat generated during battery operation. By circulating a coolant, the system extracts heat from the battery cells and transfers it away, preventing hotspots and ensuring uniform temperaturedistribution.
- Thermal Management: Liquid cooling allows for precise thermal management of individual battery cells or modules. This objective is crucial in large battery packs where temperature variations among cells can occur. By monitoring and controlling the cooling process, the system can equalize temperatures across the battery pack, ensuring consistent performance and prolonging battery life.
- Safety Enhancement: Effective cooling systems contribute to the safety of battery installations. By maintaining temperatures within safe limits, they minimize the risk of thermal runaway and potential battery failures, including fires or explosions. Cooling systemscan also aid in dissipating excess heat generated during high-demand scenarios or fast- charging situations, reducing the likelihood of thermal stress-related issues.
- Energy Efficiency: Liquid cooling systems can help improve the overall energy efficiency ofbattery systems. By keeping the batteries at optimal operating temperatures, cooling mitigatesperformance losses due to temperature-dependent effects. This can enhance the overall efficiency and performance of the batteries, ensuring they deliver the expected power output.
- Longevity and Reliability: Proper cooling plays a crucial role in extending the lifespan and ensuring the reliability of batteries. By maintaining lower operating temperatures, cooling systems can reduce the rate of degradation, slow down chemical reactions, and minimize theformation of harmful by-products, ultimately extending the battery's operational life.
- Flexibility and Adaptability: Liquid cooling systems offer flexibility in terms of design and adaptability to different battery chemistries, sizes, and configurations. They can be designedto accommodate various battery technologies, including lithium-ion, lead-acid, or flowbatteries, and can be tailored to specific cooling requirements based on the application or environment. With keeping these objectives in mind, we carried out the project.

1.3 Scope

As the cases of EV two-wheeler batteries catching fire is increasing and the risk to life creating aproblem to the general society our main need is to create this system which will activate once the temperature of the battery reaches a temperature at which the risk of combustion is achieved and quicklystart the cooling process of the battery by removing the heat from the battery and give it to the surrounding.

The system will be powered by the DC supply of the battery, hence will use a suitable motor thatwill work of the battery of the EV or if not, possible we will provide an external power source

Proper sizing and dimension testing will be done to find out proper size of the battery and whichwill give us the desired refrigerant flow rate Doing proper calculations and testing to find out the efficiency of the project on normal and extreme working conditions. These will be the desired scope of the project

1.4 Methodology

The proposed methodology of aur project is it will run on the Peltier effect. The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is namedfor French physicist Jean Charles AthanasePeltier, who discovered it in 1834.

When a current is made to flow through a junction between two conductors A and B, heat may be generated (or removed) at the junction. The Peltier heat generated at the junction per unit time is equalto,

$$Q = (\prod_A - \prod_B)I$$

Where ∏ is the peltier coefficient of the conductorAnd I is
the electric current

The Peltier coefficients represent how much heat is carried per unit charge. Since charge currentmust be continuous across a junction, the associated heat flow will develop a discontinuity if ∏A and ∏B are different. The Peltier effect can be considered as the back-action counterpart to the See beck effect (analogous to the back-emf in magnetic induction): if a simple thermoelectriccircuit is closed then the Seebeck effect will drive a current, which in turn (via the Peltier effect)will always transfer heat from the hot to the cold junction. The close relationship between Peltierand See beck effects can be seen in the direct connection between their coefficients: $\prod = TS$

A typical Peltier heat pump device involves multiple junctions in series, through which a currentis driven. Some of the junctions lose heat due to the Peltier effect, while others gain heat. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices foundin refrigerators.

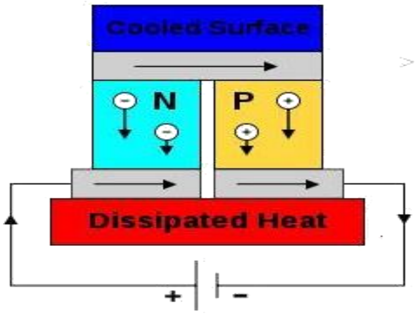

Fig. 1.1: PELTIER EFFECT

Thermoelectric materials can be used as refrigerators, called "thermoelectric coolers", or "Peltier coolers" after the Peltier effect that controls their operation. As a refrigeration technology, Peltier cooling is far less common than vapor-compression refrigeration. The main advantages of a Peltier cooler (compared to a vapor-compression refrigerator) are its lack of moving parts or circulating fluid, and its small size and flexible shape (form factor). Another advantage is that Peltier coolers do not require refrigerant fluids, such as chlorofluorocarbons (CFCs) and related chemicals, which can have harmful environmentaleffects.

The main disadvantage of Peltier coolers is that they cannot simultaneously have low cost and high-power efficiency. Advances in thermoelectric materials may allow the creation of Peltier coolers that are both cheap and efficient. It is estimated that materials with ZT >3 (about 20–30% Carnot efficiency) are required to replace traditional coolers in most applications. Today, Peltier coolers are only used in niche applications.

The Peltier effect can be used to create a refrigerator which is compact and has no circulating fluid or moving parts; such refrigerators are useful in applications where their advantages outweigh the disadvantage of their very low efficiency.

We also did use the system used by IC engine vehicles that is the radiator system, here a radiator is used to pass the hot coolant a path inside a box which has fins that remove the heat from the coolant, the heat is then dissipated to the outside and the coolant is bought to a lower pressure and temperature. A pump is used to move the coolant from the reservoir and pass it through the entire system.

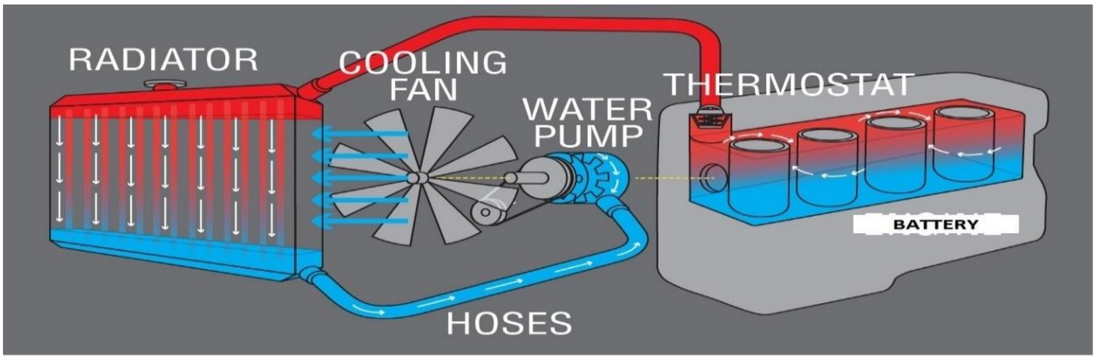

Fig.1.2: Cooling system of Battery

CHAPTER 2

Literature review

For doing our research on this subject we carried out reading of older research papers which are published on this subject and the related parts of our system. We found some research papers thru different websites and some online and the ones which we found extremely use full are listed below

Y.Lyu et al [1] studied Electric vehicle battery thermal management system with thermoelectric cooling on November 2019 and published in the book Energy Report Print ISSN: 2352-4847

An experimental investigation is performed on an advanced battery thermal management system for emerging electric vehicles. The developed battery thermal management system is a combination of thermoelectric cooling, forced air cooling, and liquid cooling. The liquid coolant has indirect contact with the battery and acts as the medium to remove the heat generated from the battery during operation. Forced air assisted heat removal is performed from the condenser side of the thermoelectric liquid casing. Detailed experiments are carried out on a simulated electric vehicle battery system. Experimental results reveal a promising cooling effect with a reasonable amount of power dissipation. Moreover, the experimental test shows that the battery surface temperature drops around 43 ºC (from 55 ºC to 12 ºC) using TEC-based water-cooling system for a single cell with copper holder when 40 V is supplied to the heater and 12 V to the TEC module. Keywords: Electric vehicle, Heater, Battery thermal management, Li-ion battery, Thermoelectric cooling

Bhagwat Shishodia [2] studied design of solar powered vapor absorption refrigeration system in November 2017 and is a patent

Summary of invention Vapour absorption refrigeration system is one of the ways to produce cooling effect which is specially used for the purpose of refrigeration and air conditioning in industry. This needs energy for heating the solution in generator which is basically achieved by using industrial waste. The industrial vapour absorption cycle needs heat source, heat exchangers and rectifiers for its working. The present invention is a solar vapour refrigeration cycle that works on direct solar thermal energy to its working. Further in the present invention heat exchangers, analyzers and rectifiers are not required for its working. This makes the present invention environment friendly and very compact, as compared to the conventional vapour absorption refrigeration cycle. Due to its compact construction and use of solar thermal energy the present invention can be used in remote and far-flung areas. Due to no moving parts in the cycle the maintenance of the solar vapor refrigeration system is also very easy and at very low cost. Existing state of the art Event thou the Li-Br vapour absorption system is known for many years its use is very limited as it requires large amount of heat at the generator. This makes the Li-Br system very bulky, requiring large heat source, so most of the industries do not use it as preferred mode for producing refrigeration and air conditioning. Currently most of the industries employs Ammonia (NH 3) as a refrigerant and water as an absorbent in their vapor absorption cycle. It also uses hydrogen to increase the cooling effect and heat exchanger and rectifiers. Drawbacks in existing state of the art

Andrii Sazanskyi, Mykhailo Khmelniuk [3] wrote an article on performance analysis of the refrigeration system for improving energy efficiency on April 2023 and in this article, they wrote

Refrigeration system holds an important role in many industrial processes. The global industrial refrigeration system market is expected to grow from USD 19.3 billion in 2019 to USD 25.7 billion by 2025, at a CAGR of 4.7%. The traditional systems (cascade/multistage) as well as hybrid system with non-zeotrope refrigerant blends are widely used for processes where more than one temperature level is required. The optimal utilization of energy saving technologies in industrial processes is a key issue for the rational use of energy resources in the process industry. Among the various existing energy saving means, the refrigeration system is a technology area that introduces several degrees of freedom. The goal is to identify the optimal refrigerant/refrigerant mixtures, the optimal temperature levels, and the best cycle's configuration to satisfy the refrigeration requirements of a technological process. It is common that hydrocarbons have great thermodynamic properties, making them efficient refrigerants. The problem is that hydrocarbons are highly flammable, it has restricted their wider adoption for some applications in the refrigeration industry, mostly for applications demanding large refrigerant charges. Targeting to reduce safety as well as regulatory problems getting up from the use of hydrocarbons, the performance of hydrocarbons and carbon dioxide mixtures as refrigerants in a standard vapor-compression cycle has studied. To take into account all energy losses in the compressor, a technique was used that allows one to assess the energy perfection of a hermetically sealed compressor during experimental studies. The given method contains indicators that estimate certain types of energy losses of a hermetic compressor using the electrical efficiency of the compressor.

Ayan Ghosh [4] wrote a chapter on A Theoretical thermodynamic analysis of R1234yf/CO2 cascade refrigeration system on April 2023 in the book Recent Advances in Manufacturing and Thermal Engineering (pp. 57-69). In this chapter he wrote

The cascade refrigeration cycle is a multi-phase thermodynamic cycle that uses multiple refrigeration cycles combined with a heat exchanger to enhance the refrigeration effect. It uses one refrigerant to condense the other main refrigerant operating at the desired evaporator temperature. This method is usually used at a temperature of 243 to 193 K when small hydrocarbon gasses or other low-boiling gasses and vapor are cooled. This paper is devoted to examine energy and exergy characteristics of the CO2—R1234yf cascade refrigeration system to obtain a good thermodynamic and environment friendly alternative via creating a virtual refrigeration system in the EES software to substitute existing refrigerants having a higher GWP value. With GWP value approximately equal to 4, R1234yf take a promising place against refrigerants in use such as R134a, R404A, R410A etc. This paper reflects that for evaporator temperature of 253 K, condenser temperature of 303 K and cascade intermediate temperature of 268 K optimum results for COP, energetic efficiency and total exergy losses are obtained. This study provides us with results of COP maximization and energetic efficiency as well as total exergy losses minimization that help us to identify the optimum working conditions for the above stated cascade refrigeration system as well as providing us with a system that is much more environment friendly than the existing combination of refrigerants being used in cascade refrigeration systems.

Bin Deng [5] did a conference paper on Modeling and simulation analysis of Electric Vehicle Battery Cooling System in April 2023. In this paper he wrote

A battery cooling system model of electric vehicle was established. The system model consists of a battery pack, a pump, a radiator, and a fan. A cooling plate was used to cool the battery pack, and the coolant flow rate in the cooling plate was controlled by the pump. The heat in the battery cooling system was released into the ambient air through the radiator. A finite element analysis model of the cooling plate was established to calculate the pressure drop of the cooling plate. A coupled dynamics model of the battery pack-radiator cooling system was established to simulate the temperature of the battery pack during charging and discharging. Tests were carried out to obtain the pressure drop of the cooling plate and the temperature of the battery pack under different working conditions. The simulation results and test results were compared and analyzed, and the accuracy of the models were verified. The effects of coolant flow rate and radiator wind speed on the liquid cooling process of the battery pack were analyzed

Dodiya Sahil Tasilbhai [6] wrote an article on Performance Analysis of Thermoelectric Cooling with Thermal Battery System for Electric vehicle on December 2022 in the International Journal of Engineering and Advance Technology. 12(2):1-7. In this article they wrote

A promising type of green transport, lithium battery-powered electric cars (EVs) have attracted a lot of attention and interest in the current years. In this study, thermoelectric cooling with forced convection was designed and possible cooling method for a thermal control battery system. Compared to free convection cooling, air cooling and TEC cooling appear TEC is the leading cooling work. Conditional tests are done on created battery thermal control battery system for EV automobile vehicles. The advanced battery thermal control battery can be a combination of TE Cooling, air cooling, and liquid cooling. There's Unobserved contact of the liquid coolant that acts as a medium to carry absent the thermally created from the battery with and amid the battery continuing. The outcome saws a promising cooling impact with a reasonable amount of energy wastage. The outcomes show that the ambient temperature is 32.5 to 30.5 and inlet temperature is 24.8 to 17.1 and then find out 2nd inlet temperature is between 13.9 to 6.4, and then after finding the lowest COP is 0.20. So, Thermoelectric cooling is the best option as compared to a simple VCRs system

Masataka Mochizuki [7] wrote an article on Heat Pipe Based Passive Emergency Core Cooling System for Safe Shutdown of nuclear Power Reactor on December 2014 in Applied Thermal Engineering 73(1):697-704. In this article they wrote

On March 11th, 2011, a natural disaster created by earthquakes and Tsunami caused a serious potential of nuclear reactor meltdown in Fukushima due to the failure of Emergency Core Cooling System (ECCS) powered by diesel generators. In this paper, heat pipe based ECCS has been proposed for nuclear power plants. The designed loop type heat pipe ECCS is composed of cylindrical evaporator with 62 vertical tubes, each 150 mm diameter and 6 m length, mounted around the circumference of nuclear fuel assembly and 21 m × 10 m × 5 m naturally cooled finned condenser installed outside the primary containment. Heat pipe with overall thermal resistance of 1.44 × 10-5 °C/W will be able to reduce reactor temperature from initial working temperature of 282 °C to below 250 °C within 7 h. The overall ECCS also includes feed water flooding of the core using elevated water tank for initial 10 min which will accelerate cooling of the core, replenish core coolant during loss of coolant accident and avoids heat transfer crisis phenomena during heat pipe start-up process. The proposed heat pipe system will operate in fully passive mode with high runtime reliability and therefore provide safer environment to nuclear power plants.

Bibin Chidambaranathan [7] Wrote an article on Thermal management system in electric vehicle batteries for environmental sustainability on April 2023 In Environmental Quality Management. In this article he wrote

Due to the extreme sensitivity of temperature in Li-ion batteries, thermal management is a significant issue that must be addressed. Since the battery in electric vehicles produces an enormous amount of heat, it reduces its efficiency and its performance. Currently, there is a need for electric vehicles (EVs) because conventional IC engines produce an enormous amount of pollution which affects the environment, so an electric vehicle produces a very small amount of pollution. It is now being recommended and used by many people. But the electric vehicle faces some major problems due to overheating in their battery module. Nowadays, battery temperature is regulated by a system called battery thermal management system (BTMS). Modern EVs use active and passive cooling systems. Thermal management tries to improve battery architecture for greater autonomy or quick charging. To meet future difficulties in thermal management, such as air or liquid cooling, are needed. As a result of the battery's overheating, the vehicle's performance, power, energy storage, charging, and discharging are all negatively impacted; hence, a reliable thermal management system for the battery is essential for resolving these problems. This study provides an overview of the BTMS of the future, beginning with the problems involving temperature and safety. The following is a list of the benefits and drawbacks of BTMSs, which are used to maintain acceptable temperatures for battery packs. In conclusion, an analysis of the progress made in developing temperature management systems for future batteries is presented. As a first look at potential BTMSs for locomotive applications, it has been proposed to conduct a comprehensive analysis and classification of both existing and potential battery management systems.

João L. Neto [8] Wrote a chapter on Development of a Battery Management System for Electric Vehicles Batteries Reuse on May 2023 in the book Sustainable Energy for Smart Cities (pp. 95-109). In this chapter they studied about

Electric Vehicles (EV) or Plug-in Electric Vehicles (PHEV) batteries can have a second life in other vehicles, in stationary electrical energy storage systems, or in academic or research projects. For this purpose, it is necessary to control and access the battery data through a Battery Management System (BMS), which is often not available in open source, therefore, it is necessary to install and/or develop a new BMS. This article discusses BMS and its features that aim to improve the performance of electric vehicles, optimizing battery capacity during charging and discharging, ensuring the safety and lifetime of a traction battery, promoting sustainable mobility. The process of developing, building, and testing a BMS is presented in this work. It should also be noted that the developed BMS is software configurable, so it can be used with other batteries of the same technology. The battery model under study and the reason to produce a new BMS are briefly reported, as well as the choice of MAX17852, as the data-acquisition Integrated Circuit (IC) used to monitor the battery cells. This work describes the steps taken during the design of all BMS components, including the Printed Circuit Boards (PCBs) design and assembly process, as well as functional tests. It is also addressed the used communication protocols between the BMS elements/components

Dineshbabu A [9] wote an article on Battery Monitoring System on April 2023. In this article he wrote

In this paper, real-time monitoring the battery based on Internet of things. For safe and reliable operation of batteries on electric vehicles, the online monitoring and states estimation of the battery is necessary. To make it convenient for every vehicle owner to monitor the battery status of their vehicles anytime and anywhere. The Battery Monitoring System will monitor the battery’s parameters continuously. Our proposed system monitors the State of Health, State of Charge and Depth of Discharge. We using an IOT technology for communicating the information. Buzzer alarm is used for indicating the abnormal condition of the battery. LCD display isused to display the information

Rui Zhao [10] Wrote an article on Thermal performance improving methods of lithium-ion battery: Electrode modification and thermal management system on September 2015 in the Journal of Power Sources 299:557-577. In this article he wrote about

Lithium ion (Li-ion) battery has emerged as an important power source for portable devices and electric vehicles due to its superiority over other energy storage technologies. A mild temperature variation as well as a proper operating temperature range are essential for a Li-ion battery to perform soundly and have a long service life. In this review paper, the heat generation and dissipation of Li-ion battery are firstly analysed based on the energy conservation equations, followed by an examination of the hazardous effects of an above normal operating temperature. Then, advanced techniques in respect of electrode modification and systematic battery thermal management are inspected in detail as solutions in terms of reducing internal heat production and accelerating external heat dissipation, respectively. Specifically, variable parameters like electrode thickness and particle size of active material, along with optimization methods such as coating, doping, and adding conductive media are discussed in the electrode modification section, while the current development in air cooling, liquid cooling, heat pipe cooling, and phase change material cooling systems are reviewed in the thermal management part as different ways to improve the thermal performance of Li-ion batteries.

In conclusion we researched and studied the above given research papers, articles, chapters and carried further research of our own paper and completed our project and report accordingly.

CHAPTER 3

Design

3.0 Theory

Liquid cooling is a widely used technique for managing the thermal conditions of batteries in applications such as electric vehicles (EVs), renewable energy storage, and portable electronics. This literature review aims to provide an overview of recent research and advancements in liquid battery cooling systems, focusing on their design, performance, and impact on battery performance and safety.

Design Considerations:

Researchers have investigated various aspects of liquid cooling system design for batteries. Key considerations include the selection of appropriate coolants, coolant flow rates, cooling channel design, and integration within the overall battery pack architecture. Several studies have examined the influence of cooling channel geometry, such as serpentine, parallel, or cross-flow designs, on heat transfer and uniform cooling distribution.

Coolant Selection:

The choice of coolant plays a crucial role in the performance and safety of liquid cooling systems. Common coolants include water-based solutions, glycol-based mixtures, and dielectric liquids. Studies have investigated the thermal properties, flow characteristics, corrosiveness, and compatibility of different coolants with battery chemistries. Additionally, the use of phase-change materials (PCMs) as secondary coolants or for thermal energy storage has gained attention due to their high heat capacity andthermal stability.

Heat Transfer and Performance:

Researchers have explored heat transfer mechanisms within liquid cooling systems to optimize their efficiency. Studies have examined the impact of flow rates, coolant temperatures, pressure drops, and heat exchanger designs on heat dissipation, thermal uniformity, and overall cooling performance. Computational fluid dynamics (CFD) simulations have been utilized to analyze flow behavior, temperature distribution, and pressure drop characteristics in cooling channels.

Battery Performance and Safety:

The effectiveness of liquid cooling systems directly impacts battery performance and safety. Research has demonstrated that maintaining optimal temperature conditions through efficient cooling can improvebattery capacity retention, reduce thermal stress, and mitigate the risk of thermal runaway. Investigationshave evaluated the impact of cooling strategies on battery lifetime, energy efficiency, power capability, and cycle life, emphasizing the importance of thermal management in maximizing overall battery performance and longevity.

System Integration and Control:

Studies have addressed the integration of liquid cooling systems with battery management systems (BMS) and thermal management control algorithms. Optimization techniques, including model-based control and predictive algorithms, have been proposed to dynamically manage coolant flow rates, adjust cooling conditions based on battery state-of-charge (SOC), ambient temperature, and operating conditions. Integration of temperature sensors and thermal feedback loops has been explored to enhancereal-time control and monitoring of cooling system performance.

3.1 PELTIER DEVICE

The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named for French physicist Jean Charles AthanasePeltier, who discovered it in 1834. When a current is made to flow through a junction between two conductors A and B, heat maybe generated (or removed) at the junction. The Peltier heat generated at the junction per unit time is equal to, **Q = (∏A - ∏B)I**

Where ∏ is the Peltier coefficient of the conductorAnd I is the electric current

The Peltier coefficients represent how much heat is carried per unit charge. Since charge currentmust be continuous across a junction, the associated heat flow will develop a discontinuity if ∏A and ∏B are different. The Peltier effect can be considered as the back-action counterpart to the See beck effect (analogous to the back-emf in magnetic induction): if a simple thermoelectric circuit is closed then the See beck effect will drive a current, which in turn (via the Peltier effect)will always transfer heat from the hot to the cold junction. The close relationship between Peltierand See beck effects can be seen in the direct connection between their coefficients: ∏ = TS. A typical Peltier heat pump device involves multiple junctions in series, through which a currentis driven. Some of the junctions lose heat due to the Peltier effect, while others gain heat. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices foundin refrigerators.

Thermoelectric materials can be used as refrigerators, called "thermoelectric coolers", or "Peltiercoolers" after the Peltier effect that controls their operation. As a refrigeration technology, Peltiercooling is far less common than vapor-compression refrigeration. The main advantages of a Peltier cooler (compared to a vapor-compression refrigerator) are its lack of moving parts or circulating fluid, and its small size and flexible shape (form factor). Another advantage is that Peltier coolers do not require refrigerant fluids, such as chlorofluorocarbons (CFCs) and related chemicals, which can have harmful environmental effects.

The main *disadvantage* of Peltier coolers is that they cannot simultaneously have low cost and high-power efficiency. Advances in thermoelectric materials may allow the creation of Peltier coolers that are both cheap and efficient. It is estimated that materials with ZT >3 (about 20–30%Carnot efficiency) are required to replace traditional coolers in most applications. Today, Peltiercoolers are only used in niche applications. The Peltier effect can be used to create a refrigerator which is compact and has no circulating fluid or moving parts; such refrigerators are useful in applications where their advantages outweigh the disadvantage of their very low efficiency.

3.2 THERMOELECTRIC COOLING

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Suchan instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC). They can be used either for heating or for cooling (refrigeration), although in practice the main application is cooling. It can also be used as a temperature controllerthat either heats or cools.

This technology is far less commonly applied to refrigeration than vapor-compression refrigeration is. The main advantages of a Peltier cooler (compared to a vapor-compression refrigerator) are its lack of moving parts or circulating liquid, near-infinite life and invulnerabilityto potential leaks, and its small size and flexible shape (form factor). Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient.

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect). However, a well-designed Peltier cooler will be a mediocre thermoelectric generator and vice-versa, due to different design and packaging requirements.

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when DC current flows through the device,it brings heat from one side to the other, so that one side gets cooler while the other gets hotter.

The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.

3.3 CONSTRUCTION OF PELTIER DEVICE

Two unique semi-conductors, one n-type and one p-type, are used because they need to have different electron densities. The semi-conductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When avoltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semi-conductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side end of the device where the heat sink is.TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

Some benefits of using a TEC are:

- No moving parts so less maintenance is required
- No chlorofluorocarbons
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration
- Has a long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Is controllable via changing the input voltage/current
- Some disadvantages of using a TEC are:
- Only a limited amount of heat flux is able to be dissipated
- Relegated to applications with low heat flux

Not as efficient, in terms of coefficient of performance, as vapor-compression systems

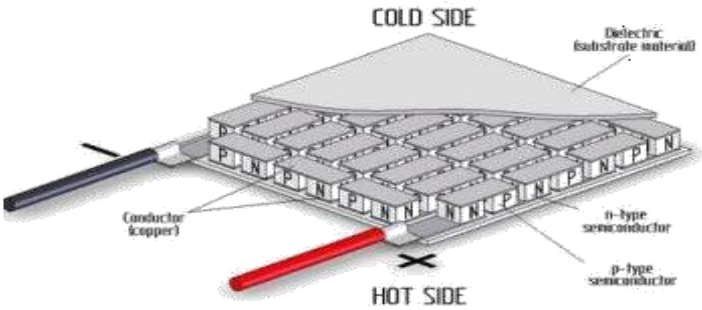

Fig.3.1: PELTIER MODULE (ALTERNATE VIEW)

A single-stage TEC will typically produce a maximum temperature difference of 70°C (126°F) between its hot and cold sides. The more heat moved using a TEC, the less efficient it becomes, because the TEC needs to dissipate both the heat being moved, as well as the heat it generates itself from its own power consumption. The amount of heat that can be absorbed is proportionalto the current and time.

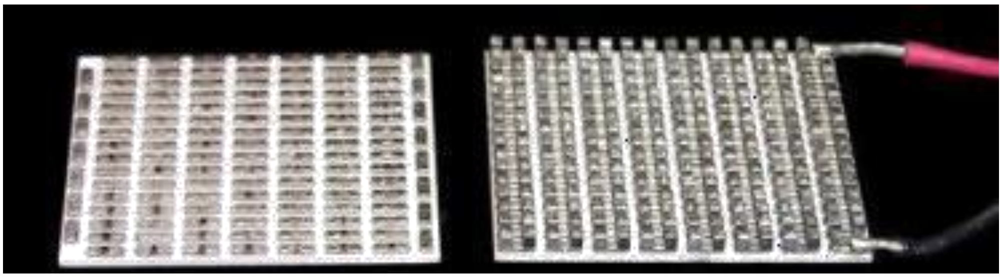

Fig.3.2: CUT SECTION VIEW OF A PELTIER MODULE TEC1-12706

W=PIt

Where P is the Peltier Coefficient, I is the current, and t is the time. The Peltier Coefficient is dependent on temperature and the materials the TEC is made of. Thermoelectric junctions are about 4 times less efficient in refrigeration applications than conventional means (they offer around 10-15% efficiency of the ideal Carnot cycle refrigerator, compared with 40–60% achievedby conventional compression cycle systems (reverse Rankine systems using compression/expansion). Due to this lower efficiency, thermoelectric cooling is generally only used in environments where the solid-state nature (no moving parts, low maintenance, compact size, and orientation insensitivity) outweighs pure efficiency.

Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and coldside heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters. Requirements for Thermoelectric materials

- Narrow band-gap semiconductor because of room temperature operation
- Heavy elements because of their high mobility and low thermal conductivity
- Large unit cell, complex structure
- Highly anisotropic or highly symmetric
- Complex composition

Common thermoelectric materials used as semi-conductors include bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys. Of this bismuth telluride is the most commonly used. New high-performance materials for thermoelectric cooling are being actively researched.

3.4 IDENTIFICATION OF PELTIER MODULE

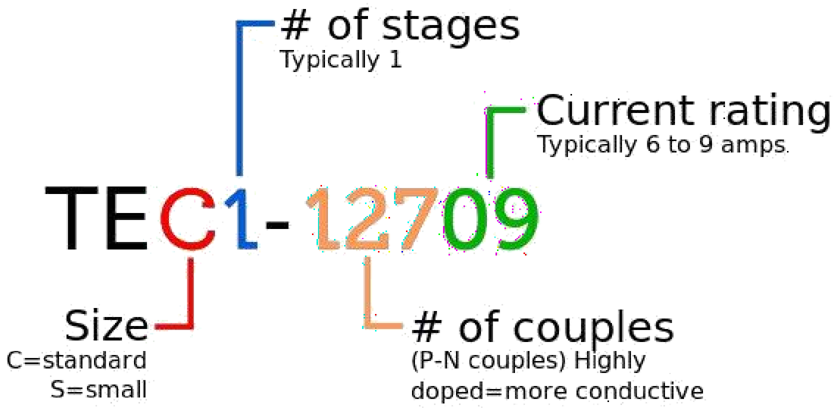

Fig.3.3: IDENTIFICATION OF PELTIER MODULE

Peltier elements all conform to a universal identification specification The vast majorityof TECs have an ID printed on their heated side.

These universal IDs clearly indicate the size, number of stages, number of couples, and current rating in amps, as seen in the adjacent diagram.

3.5 ASSEMBLY OF PELTER MODULE

Step 1: The TEC – 12706 is sandwiched between two heat sinks as shown below using an adhesive.Step 2: Place the fans as shown below Table.no 1Assembly of Pelter Module

Surface	Direction of air circulation
Hot surface	Inwards – towards the module
Cold surface	Inwards – towards the module

Table.3.1 Assembly of Pelter Module

Step 3: Attach Screws and bolts. Tighten one by one on all four sides till the contact pressure isoptimum.

Step 4: Make electrical connections.

3.6 BATTERY MANAGEMENT SYSTEM

A battery management system (BMS) is an electronic system designed to monitor and control rechargeable batteries. It is commonly used in various applications, including electric vehicles (EVs), renewable energy systems, portable electronics, and industrial equipment.

The primary purpose of a BMS is to ensure the safe and optimal operation of the battery. Here are someof the key functions performed by a typical battery management system:

Battery Monitoring: The BMS continuously monitors the battery parameters such as voltage, current, temperature, and state of charge (SOC). This information helps assess the battery's health, performance,and remaining capacity.

Cell Balancing: In multi-cell battery packs, individual cells may have slight variations in capacity or voltage. The BMS ensures cell balancing by equalizing the charge across cells, which improves overallpack performance and extends the battery life.

Overcharge and Over discharge Protection: The BMS safeguards the battery from overcharging (excessive voltage) and over discharging (excessive discharge voltage), which can lead to damage or reduced battery life.

Thermal Management: Monitoring battery temperature is crucial for preventing overheating, which can degrade the battery or cause safety hazards. The BMS regulates temperature by controlling coolingsystems or limiting charging/discharging rates.

State of Charge Estimation: The BMS uses algorithms to estimate the battery's state of charge,providing an indication of how much energy remains in the battery. This information helps in determining the battery's range and preventing over discharge.

Fault Diagnosis and Protection: The BMS detects and responds to abnormal conditions like short circuits, cell failures, or other malfunctions. It may isolate faulty cells, activate protective measures, ortrigger alarms to ensure safety and prevent further damage.

Communication and Data Logging: BMS often includes communication interfaces such as CAN (Controller Area Network) or Ethernet to communicate with other systems, allowing external monitoring, control, and data logging for diagnostics and analysis.

The specific features and capabilities of a BMS can vary depending on the application and battery type.For example, a BMS for an electric vehicle may have additional features like regenerative braking control, power distribution, or integration with the vehicle's onboard systems.

Overall, a battery management system plays a crucial role in maximizing battery performance,extending its life, and ensuring safe and reliable operation.

3.7 BATTERY THERMAL MANAGEMENT SYSTEM

Battery thermal management systems (BTMS) are designed to regulate and control the temperature of batteries in various applications, including electric vehicles, hybrid vehicles, energy storage systems, and portable electronics. The primary purpose of a BTMS is to maintain optimal operating conditionsfor the batteries, ensuring their performance, safety, and longevity. Here are the key components and functions of a typical battery thermal management system:

- Temperature Sensors: Temperature sensors are strategically placed within the battery pack to monitor the temperature at different locations. These sensors provide real-time temperature data to the BTMS for effective temperature management.
- Cooling System: The cooling system is responsible for removing excess heat generated by the batteries.

It typically consists of a coolant (liquid or gas) and a heat exchanger. The coolant absorbs heat from the batteries and transfers it to the heat exchanger, where it is dissipated into the surrounding environment.

- Heating System: In cold weather conditions, a heating system may be incorporated into the BTMS to maintain optimal battery temperature. The heating elements provide warmth to the battery pack, preventing temperature drops that could negatively impact battery performance and lifespan.
- Thermal Insulation: Thermal insulation materials are used to minimize heat transfer between the battery pack and the external environment. This helps to maintain a consistent temperature within the battery pack and improve overall thermal efficiency.
- Battery Management System (BMS) Integration: The BTMS is often integrated with the Battery Management System, which monitors and manages various aspects of battery operation, including temperature, voltage, current, and state of charge. The BMS uses the temperature data from the BTMS to optimize battery performance and protect against thermal-related issues.
- Control Algorithms: Advanced control algorithms are employed to regulate the cooling or heating systems based on temperature measurements and predefined temperature setpoints. These algorithms ensure that the battery temperature remains within a safe and optimal range.
- Safety Features: BTMS incorporates safety features to prevent battery overheating or thermal runaway. This may include temperature limits, thermal shutdown mechanisms, and fault detection systems that trigger protective actions in case of temperature anomaly

3.8 CALCULATIONS

Before making decisions on which components to use for the box, theory had to be reviewed and some preliminary calculations performed.

- ### Passive Heat Load

The passive heat load for the unit was first calculated based upon a 25cm x 25cm x 25cm interior volume. Two inches of polystyrene insulated was assumed (k=0.027w/mK). Also included were a rubber seal on the door which was 50 cm2 in area.

$$q_{tot} = k_{ins} \frac{\Delta T}{\Delta x} + k_{rubber} \frac{\Delta T}{\Delta x}$$

Where: q_{tot} is the heat transfer in watts, k_{ins} is the resistance to heat transfer, and k_{rubber} is 0.014w/mK ΔT is assumed to be 20 °C and Δx is 0. 50m. This gives q_{tot} of 10 W.

- **Active Heat Load**

The active heat load is the equivalent of the cooling power that the unit will need to provide when the sample at room temperature is placed in the container. It was decided that one liter of water at room temperature would be the test sample for which all calibration and calculationswould be made. The time to cool this load from 25 °C to 5 °C was determined to be 1 hour, or3600 seconds. Based on these values:

$$Q = c_p \, m \Delta T$$

If the Cp of water is 4.14 KJ/kg*K, then Q = 82800J and dividing by 3600s to get power (W), Qdot = 23 W for the active heat load. Therefore, the total load is 23 + 11 W = 34 W of power required. This assumes that there is no thermal resistance between the sample and the air in theunit. This may be an incorrect assumption but it does overestimate the cooling load.

- **Heat Load required to be dissipated by Heat Sink**

The Peltier module is running at 12V and 5.2 amps of current. The following Vin vs. I graph[1] showsa normal operating range of the TEM**.**

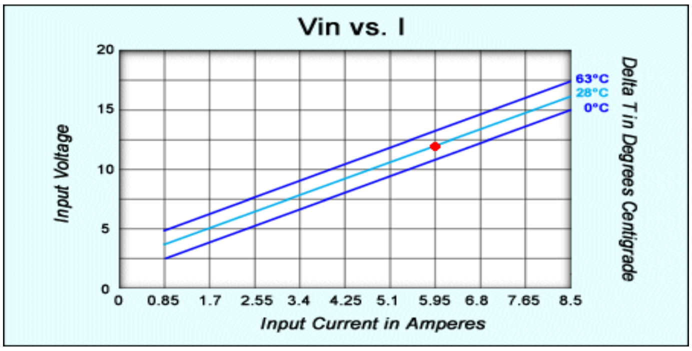

Fig3.4: Thermoelectric Module Performance

The power consumed by the TEM is assumed in the worst-case scenario to be added to the heat on the hotside.

$$q_{hot} = P_{TEC} + \frac{Q_{passive} + Q_{sample} + Q_{safetyfactor}}{2} \qquad (5)$$

Division by two denotes that we have two TEM's, two hot side heat sinks and two cold side heat sinksto improve system efficiency. Therefore, qtot= 107W. This is the maximum heat load to the hot side of each TEC and therefore each of the heat sinks.

3.9 Maximum Temperature Rise on Hot Side of TEC

Applications	Stationary needing high load currents and endurance	EVs, industrial, Nissan Leaf, Chevy Volt and BMWi3	Industrial, electric powertrain (Tesla)
Temperature range charge	(-20 to 55 °C)	(-0 to 55)	(-0 to 45)
Temperature range dis-charging	(-30 to 55 °C)	(-20 to ~55)	(-20 to 60)
Installed energy 2016 [USD/kWh]	~570	~390	~350
Installed energy 2030 [USD/kWh]	~230	~155	~135

Table.3.2 Temperature Rise on Hot Side

Max temp rise = 107W x 0.17 °C/W = 18.2 °C

The ΔT over the TEC is 25 – 5 +18.2 (°C) = 38.2 °C, where 25 is the ambient temperature on the hot side, 5 is inside desired temperature and 18 is the added heat load. The following table will show that the operating point for heat removal of 18W (for each TEC) and a ΔT of 38°C only requires a current draw of 4.5 Amps.

3.10 COOLING LOAD

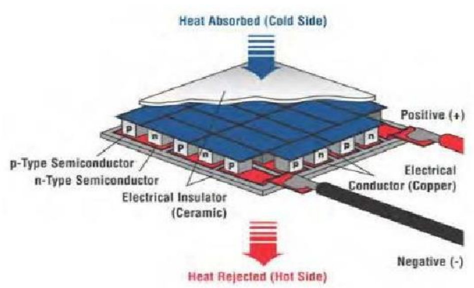

Figure 4: A Cutaway of Thermoelectric Module

- Cold side temperature (T_c)
- Hot side temperature (T_h)
- Operating temperature difference (ΔT), which is the temperature difference between T_h and T_c.
- Amount of heat to be absorbed at the TEC's cold surface. This can also be termed as heat load. It is represented as (Q_c) and the unit is Watts
- Operating current (I) and operating voltage (V) of the TEC.

Fig.3.5. Shows a cutaway of thermoelectric module

The most difficult and important factor to be accurately calculated for a TEC is the amount of heat to be removed or absorbed (*Qc*) by the cold side of the TEC. In this project *Qc*was calculated by finding the product of finding the product of mass flow rate of air, specific heat of air and temperaturedifference. Here the temperature difference system in the difference between the inlet temperature and outlet temperature of the cooling system. The Mathematica liquation for *Q c*is as shown below.

$$Q_c = \dot{m} C_p \Delta T$$

Fig.3.6. Formula for cooling load

3.11 LAYOUT

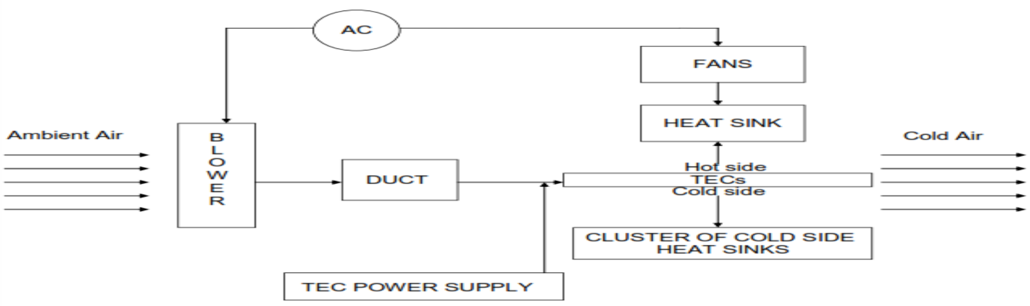

Figure 1: Block diagram of the thermoelectric cooled cooling fan.

Fig3.15. shows the layout of thermoelectric cooler

According to the above figure we have shown the basic layout of how a tec plate does the effectivecooling and gives us the desired cooling, firstly a blower is used to suck in the ambient air from theoutside and pass it to the tec

When the tec gets the signal that cooling is needed the tec power supply switches on and a closed circuit is created, the tec then starts its cooling process by giving heat out from one side and cooling theother side The fan and heat sink pull away the heat given from the tec and maintain its temperatue, as this is goingon the ambient air passes over the tec surface giving the ambient air its coolness and passes the air forwardto the battery to be cooled, in this way this layout was the most effective in giving us effective battery cooling

CHAPTER 4

CODING FOR LBCS

4.1 MODELING

For the testing purpose of our Arduino system, we firstly used the software available to us that was wokwik.com. with the use of this tool, we were able to simulate a basic Arduino system with a thermostat,a digital board for showing the readings, a dial to adjust the temp and a relay to simulate a motor. In this simulation we showed the that when the thermostat reaches a certain temperature which was set by us in the Arduino board, the Arduino circuit switches on the motor to start the cooling process, and once when the desired temperature has been reached then the Arduino board switches off the motor, and the cycle continuous and repeats itself.

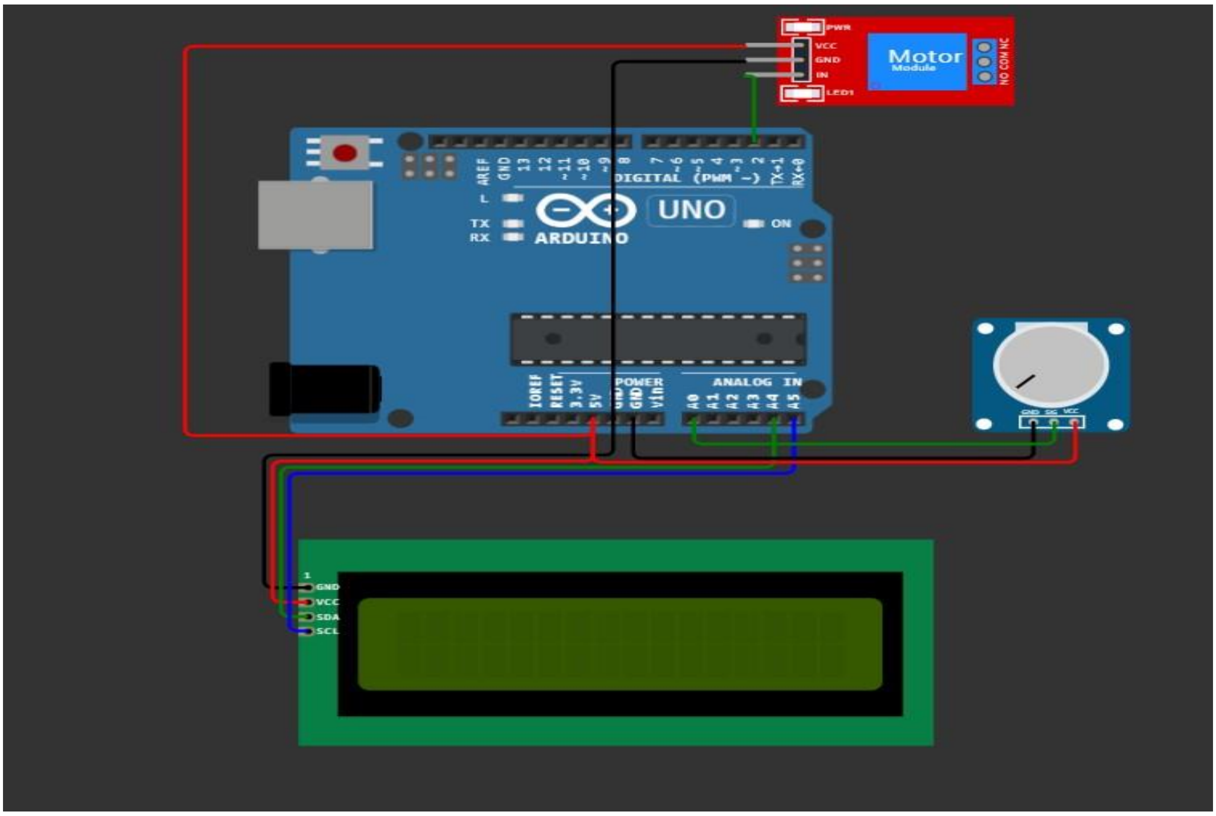

Fig4.1. Arduino board OFF

When the simulation is off the parts are inactive and don't show any reading. When we click on the start simulation is when the display is turned on the temperature can be set.

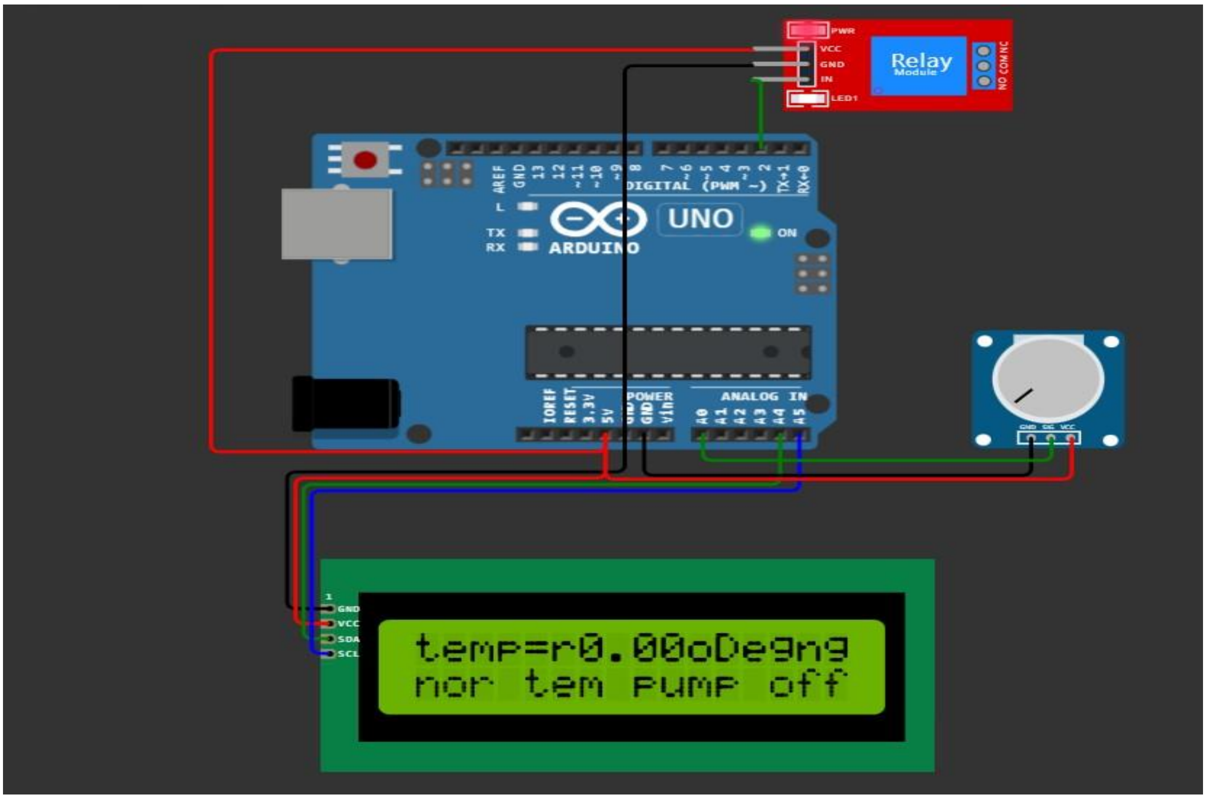

Figure 4.2. Simulation is turned ON

As we can see in the figure the display is turned on and it shows that the temperature is not currently set and thatthe pump is off and need the temperature to be set to do the working

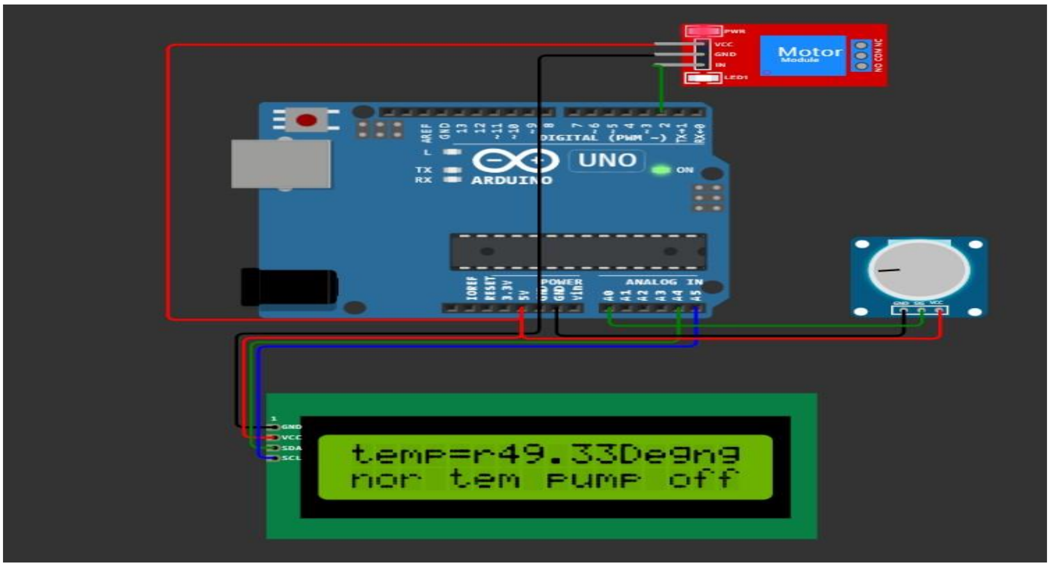

Figure.4.3. Temperature is set to 49deg

The dial is turned on the operating temperature is set to 49deg and that the Arduino has set that inthis temperature range the pump is switched Off and once this temperature reaches beyond this operating temperature the pump switches ON

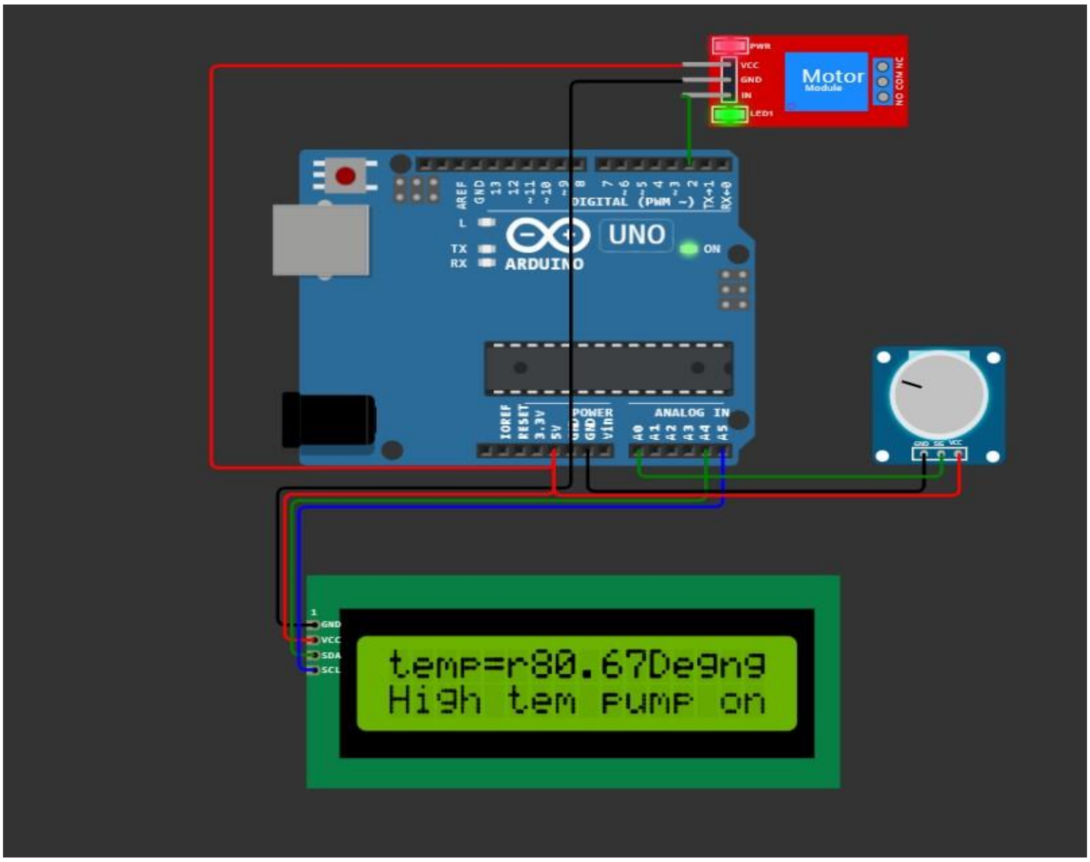

Figure 4.4. Pump is switched ON

When the temperature reaches beyond the set temperature range, then the Arduino board switches the motor on and the pump starts the cooling process. And in this way the battery cooling system works with the help of a Arduino board in the simulation

4.2 CODE

```
#include <Wire.h>

 #include <LiquidCrystal_I2C.h>
 LiquidCrystal_I2C lcd(0x27, 16, 2);


 const int currentPin = A0;
 double adccurrent = 0;
```

```
double currentValue = 0;

const int rel = 2;
double power ;
void setup()
{lcd.init();
  lcd.backlight();
  Serial.begin(9600);
  pinMode(rel, OUTPUT);
 lcd.setCursor(0, 0);
  lcd.print("Battery cooloing sys");
  delay(2000);
}

void loop()
{

  adccurrent = analogRead(currentPin);
  currentValue = (adccurrent / 3) ;



 lcd.setCursor(0, 0);
  lcd.print("temp=");
  lcd.setCursor(6, 0);
  lcd.print(currentValue);
  lcd.setCursor(11, 0);
  lcd.print("Deg");

  if (currentValue>=50)
  {    digitalWrite(rel, HIGH);
 lcd.setCursor(0, 1);
 lcd.print("High tem pump on");
```

```
  }
  else{   digitalWrite(rel,LOW);


 lcd.setCursor(0, 1);
  lcd.print("nor tem pump off");



  }




}
```

With the use of this code, we set the Arduino board operating and the temperature range.

CHAPTER 5

MANUFACTURING OF LBCS

After we had done collecting all our parts and made the final decision to start the building of our project, we started the manufacturing

For manufacturing we didn't need to go a workshop but did all the required building from our own room. The manufacturing took 3 days to properly complete and all the members of our group contributed their time to build this project.

We used a piece of acrylic glass to mount the parts of the system and display the project neatly. To do so we used a drill-to-drill holes and mount the parts using screws. The mounting was going easy but we faced issue as the drilling holes cracked the first piece of acrylic, so we had to change the acrylic with a mor thicker piece to support the weight of the parts.

5.1 Parts Used for LBCS

Our system is design of the principle of pelter effect in which we use a thermoelectric cooler to carry out the system cooling, while designing we made a list of the necessary parts and removed their specification to find the suitable parts for our use.

The list of the main parts we used for the making of our project

ARDUINO:

Arduino is an open-source electronics platform that consists of both hardware and software components. It provides a flexible and user-friendly environment for creating and prototyping various electronic projects. Arduino boards are equipped with microcontrollers that can be programmed to control a wide range of devices and interact with the physical world.

The Arduino hardware typically consists of a microcontroller board, which serves as the brain of the system, and a variety of input and output pins. These pins can be used to connect sensors, actuators, displays, and other electronic components to the Arduino board. Arduino boards comein different shapes and sizes, offering different capabilities and features to suit different projectrequirements.

Arduino software, often referred to as the Arduino IDE (Integrated Development Environment), is a programming environment used to write and upload code to Arduino boards. It provides a simplified programming language based on C/C++, making it accessible even to those with littleor no programming experience. The Arduino IDE includes a set of libraries and functions that simplify the process of interacting with the hardware and controlling various components.

Using the Arduino platform, you can create a wide range of projects such as robotics, home automation systems, wearable devices, environmental monitoring systems, interactive art installations, and much more. The versatility and popularity of Arduino have contributed to a large and active community of makers, hobbyists, and professionals who share projects, code examples, and support through online forums and resources.

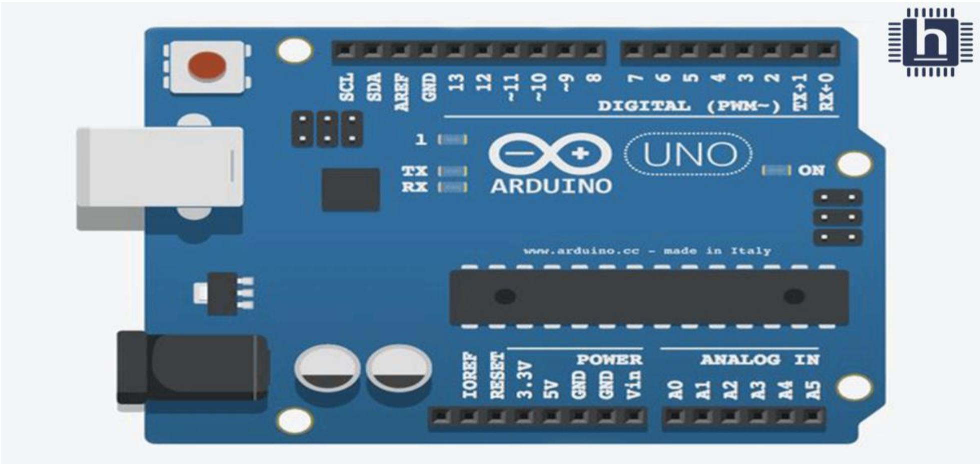

Fig.5.1. Arduino Board

Thermoelectric cooler

A thermoelectric cooler, also known as a thermoelectric module or a Peltier cooler, is a device thatutilizes the thermoelectric effect to create a temperature difference between its two sides. It operates based on the principle of the Peltier effect, discovered by Jean Charles Athanase Peltierin 1834.

A thermoelectric cooler consists of multiple thermoelectric modules, which are made of semiconductor materials, typically bismuth telluride or lead telluride. These modules consist oftwo different types of semiconductor materials, known as p-type and n-type, that are connectedin series. When an electric current is applied to the thermoelectric module, it causes electrons tomove from the n-type material to the p-type material, resulting in a temperature difference acrossthe module.

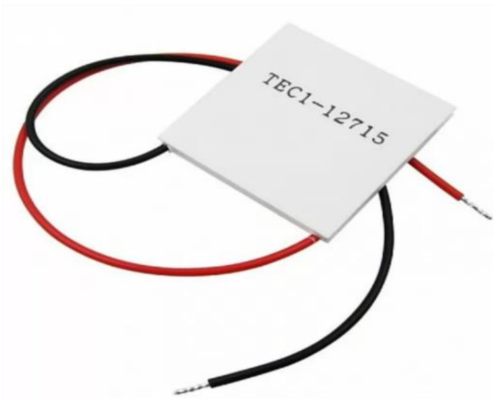

Fig.5.2. Thermoelectric cooler

One side of the thermoelectric cooler is the cold side, which absorbs heat from the environment orthe object to be cooled. The other side is the hot side, which dissipates the heat generated by thethermoelectric effect.

By continuously applying an electric current, the thermoelectric cooler can create and maintain a temperature differential, allowing for cooling on the cold side.

Water pump:

The water pump was used to move the refrigerant from the reservoir and circulate the current amount of refrigerant throughout the entire system.

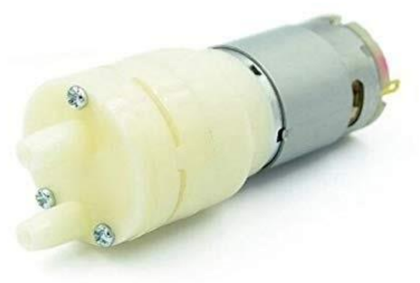

Fig.5.3. R365-water pump

The water pump we used was a R365- 12v water pump the pump can handle pumping heated liquids up to a temperature of 80°C and when suitably powered can suck water through the tube from up to 2m and pump water vertically for up to 3m. This immersible pump can be used to water your plants, make a fountain or waterfall, and even change your fish tank water. It works quietly with the sound level under 30db. The pump has a filter inside as well as a suction cup which can help stick it to smooth surfaces tightly.

Cooling fan The cooling fan used is to remove the heat from the hot side of the tec and keep in in operating temperature

The fan Used by us was a 120 X 120 X 25mm Cabinet 4.7 Inch Fan Square 12 V DC CPU Cooling Fan

Fig.5.4. Cooling fan

The specification of the fan are as follows:

- 1.92-Watt Power Consumption.
- Size ~120mm x ~120mm x ~25mm
- Voltage consumption: 12 v
- Current Consumption: .16 A
- This fan also can be run using a 12v 0.5Amp Adapter or a 12v Battery.
- Comes with Mounting Holes

Temperature sensor

The temperature sensor is placed on the battery to constantly monitor its temperature and send thereading to the Arduino unit present inside

Fig.5.5. Temperature sensor

DS18B20 Waterproof Digital Temperature Sensor Probe 100cm is a 1-Meter-Long Waterproof, sealed and pre-wired digital temperature sensor probe based on DS18B20 sensor. It is very handy for when you need to measure something far away, or in wet conditions. Because they are digital, you don't get any signal degradation even over long distance.

The specification of the sensor is as follows:

- Usable temperature range: -55 to 125°C (-67°F to +257°F)
- 9-to-12-bit selectable resolution
- Uses 1-Wire interface- requires only one digital pin for communication
- Unique 64-bit ID burned into chip
- Multiple sensors can share one pin
- ±0.5°C Accuracy from -10°C to +85°C
- Temperature-limit alarm system
- Query time is less than 750ms
- Usable with 3.0V to 5.5V power/data

Battery

A typical 12v battery of a motorcycle is used to demonstrate a ev two wheeler battery

Fig.5.6. 12v battery

Pipe

Pipe is used to connect the reservoir to the pump and to the rest of the system to provide coolant

Fig.5.7. Silicon Pipe

Heat sink

The heat sink is placed near the fan and acts as a radiator to the coolant, it removes the heat from the coolant and dissipates it to the surrounding atmosphere air by naturally cooling.

Fig.5.8. Heat sink

5.2 BILL OF MATERIAL

Sr.no	Part name	Quantity	Material
1	Pump	01	Steel, Plastic, Rubber
2	Thermoelectric cooler	01	Aluminum
3	Heat sink	01	Aluminum
4	Fan	01	Plastic
5	Pipe	1m	Plastic
6	Arduino microcontroller	01	
7	Coolant	500ml	water
8	Reservoir	01	Plastic box

Table.5.1. Bill of Material

5.3 COST ESTIMATION

Total Cost = [Machining Cost + Raw Material Cost + Travelling Cost +Report Making cost]

= 12000/- (Approximately)

CHAPTER 6

Testing of LBCS

As testing with a lives battery was dangerous, for our safety we used a dead battery as a place holder for the EV battery. To simulate an increase in the temperature of the battery we used a heat source to indicate an increase in the temperature.

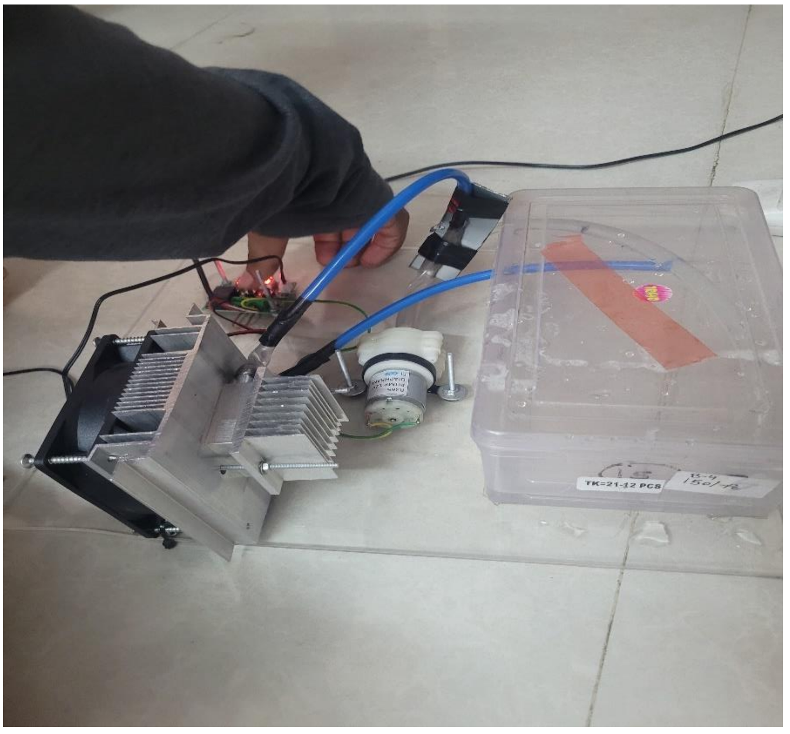

Fig.6.1 Setting the temperature

Firstly, by using the industrial board we set the temperature range at which the battery operates efficiently, then we set the temperature which was beyond the operating temperature of the battery.

Once this was set, we started the system, the temperature when set indicates the temperature on the 8-bit board so we can clearly see the temperature.

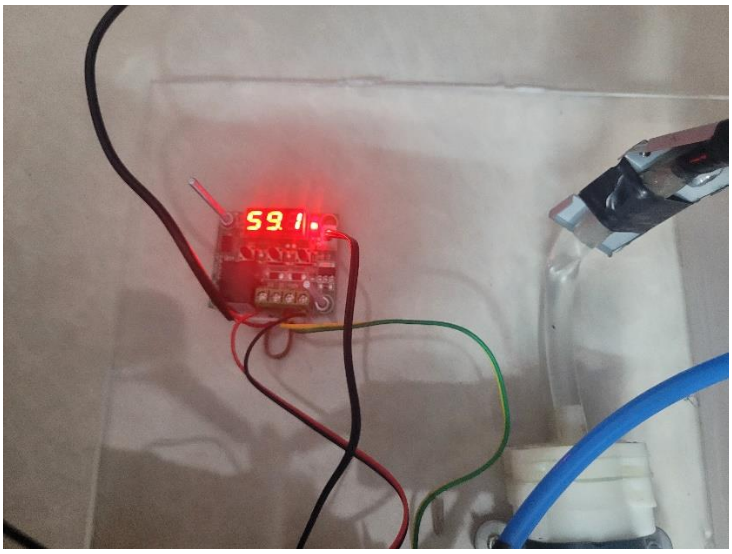

Fig.6.2. Temperature is set at 59deg

Now to show the operating of the cooling system we heated the temperature sensor using a lighter, as the temperature sensor was heated the display board shoed the live change in the temperature, and as the temperature hit the max limit is when the system started.

When the max temperature was sensed the system send a signal to the water pump and the fan and the system starts

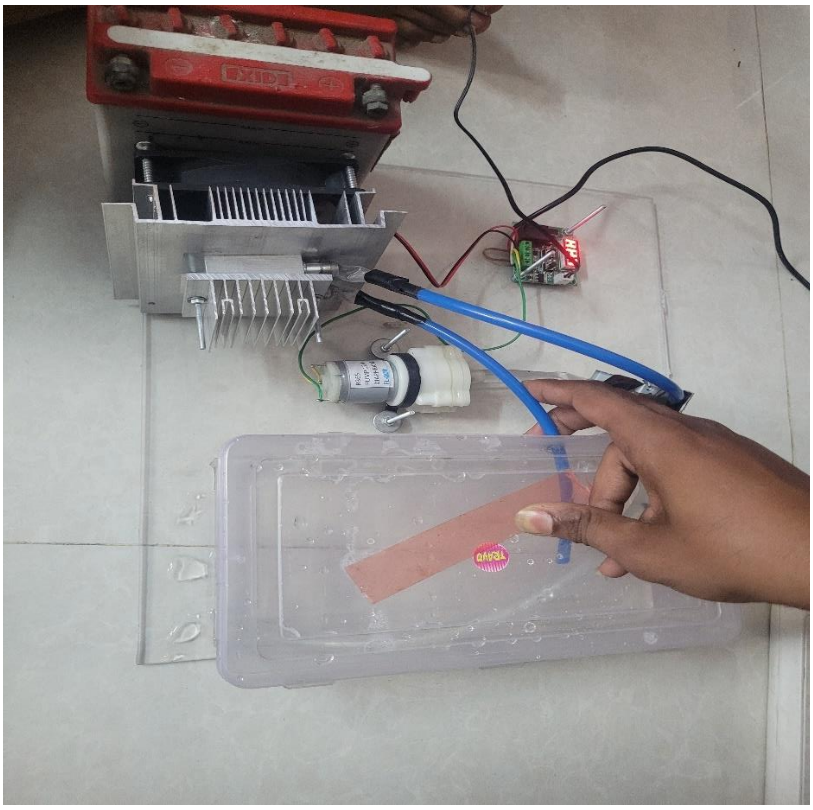

Fig.6.3 System operating

The system was efficiently pumping the coolant and an operating.

We did face a issue in testing at the fan would shut down so we had to open up the wiring and check the connections again. We found that there was a loose connection that when the fan started the vibration would knock the wire loose and stope the system

Apart from this issue the testing was done successfully and the results of the test were noted down.

When the battery reaches its max temperature the temperature at which the system can't do much cooling it takes the decision to completely shut down the entire vehicle and cutoff all the power going to the system.

Fig.6.4. temperature reaching extreme high and system shutting down

Fig.6.5. Group members fixing small leak

Fig.6.6. System at room temperature

CHAPTER 7

RESULT

After successfully conducting the testing of the LBCS we noted the results down and as per the test we found out the following

Firstly, we found out that the normal operating temperature of the lithium-ion batteries lies between -20˚ to 60˚c so for demonstration we set the temperature to about 59˚c, this will simulate the maximum operating temperature.

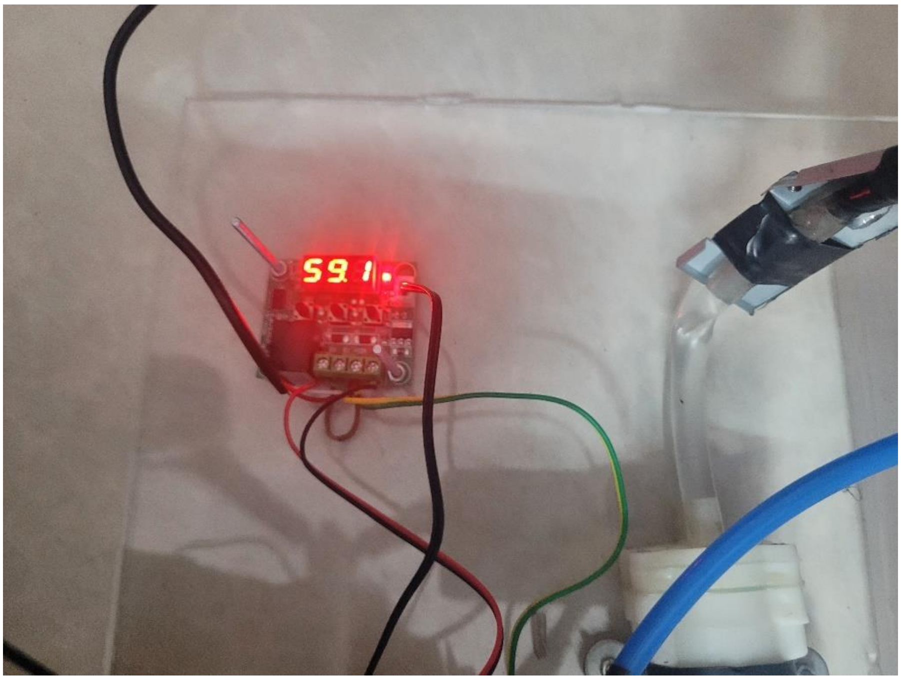

Fig.7.1 Temperature is set to 59˚c

Once this temperature is reached the system turns on and starts the cooling process. It starts to circulate the coolant thru the entire system in the end cooling the battery. For testing purposes, we set a temperature of 80˚c and conducted our test

From this temperature we measured out how much time it takes our system to come back to its operating temperature and also how long the system takes to come to room temperature. As per our tests our system took

- 00.12.37 seconds to reach from 80˚c to 59˚c
- 00.17.37 seconds to reach from 59˚c to 31˚c
- 00.28.97 seconds to reach from 80˚c to 31˚c

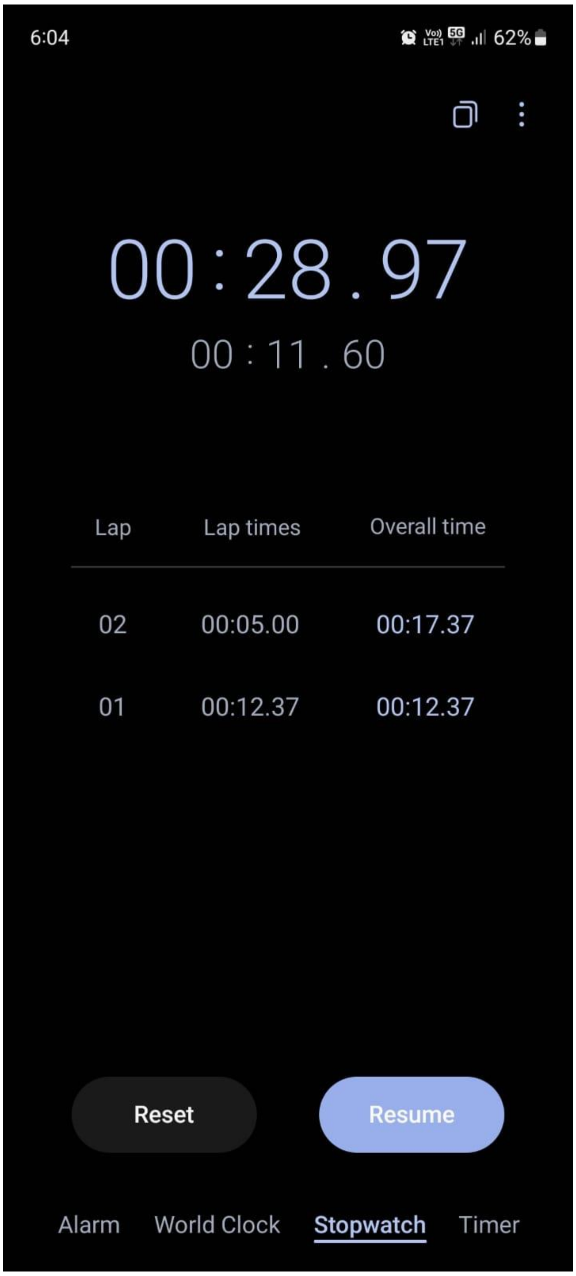

Fig.7.2 Time taken by the system for cooling

CHAPTER 8

CONCLUSION

In conclusion, the battery cooling system project has successfully addressed the critical issue of thermal management in battery systems. By implementing an efficient cooling system, several benefits have been achieved, including improved battery performance, enhanced safety, and increased overall lifespan of the batteries.

Through meticulous research and development, the project team designed and implemented a robust cooling system that effectively manages the temperature of the batteries during operation. The system employs advanced techniques such as active cooling, passive cooling, or a combination of both,depending on the specific requirements of the battery application.

The experimental results obtained from testing the cooling system demonstrated its effectiveness in maintaining optimal battery temperatures. The system effectively mitigated the risk of overheating, which can cause degradation, reduced capacity, and even safety hazards in battery cells.

Furthermore, the project successfully integrated the cooling system into the existing battery management system (BMS) infrastructure. This integration allowed for real-time monitoring and control of the cooling system, ensuring precise temperature regulation and preventing any potential thermal runaway events.

The economic viability of the cooling system was also considered throughout the project. By carefully selecting cost-effective components and implementing energy-efficient cooling techniques, the system demonstrated its potential for widespread adoption across various battery-powered applications.

It is important to note that while this project focused on battery cooling systems, there is still room for further research and improvement. Future work could explore alternative cooling technologies, such as phase-change materials or thermoelectric cooling, to optimize thermal management further.

Overall, the battery cooling system project has made significant strides in addressing the critical issue of thermal management in battery systems. The successful implementation of an efficient cooling system has paved the way for enhanced battery performance, improved safety, and extended battery lifespan, thereby contributing to the advancement and widespread adoption of battery-powered technologies.

CHAPTER 9

Future Scope OF LBCS

In the future we have planned to add a solar panel, this panel will operate the system all alone, the system firstly relying on the existing battery of the EV, but this was reducing the charge in the battery which ledto reduce in mileage, hence to compensate this loss we will be adding a solar panel at the back of scooterto charge an extra battery which will run the water pump and the Arduino system.

Also, we will be planning to add a radiator, this will assist in the quick cooling of the coolant, it will help in removing the heat and pressure of the coolant and changing it to a lower pressure and temperature, the current system only uses a heat sink and a fan to remove the heat from the coolant so adding a radiator will give it a extra way to reduce its pressure.

We also would like to implement this system not only as a modification but to actually have this system preinstalled in the EV by the manufacturer as a safety measure to battery heating, this would be a great achievement for our project.

These where few of the future planning of upgrades and add-ons we are planning for our project

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