SOLAR POWERED WATER COOLING SYSTEM FOR AN e-VEHICLE

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ABSTRACT

The future of automobile is the electric vehicles. The booms of e-cars in the automobile industry have created various domains of research aspects. There are lots of boons and banes in the advancements of these electric cars. The major hindrances in the development of the e-cars are waste disposals and over-heating of the tractive system. This work majorly deals with the over-heating of the tractive system. On further study, we found that the over-heating of the motor controller would reduce the performance of the vehicle. Our cooling system "SOLCOOL" uses a water cooled system which is driven by the solar energy. The cooling system consists of solar panel, a pump, a radiator, auxiliary battery and concealed tubes. The solar panel collects the solar energy and coverts them into electric current which would be stored in the auxiliary battery. This battery provides power for the pump. The pump circulates the water throughout the tractive system of the electric vehicle. The water carries the heat from the controller of the tractive system. The temperature of the water leaving the controller would be higher than the atmospheric temperature. This temperature is reduced after passing through the radiator. This process is repeated as a loop in order to regulate the temperature constantly. Hence a system was developed that would maintain the temperature of the controller within the desirable limits. Thus, the temperature of the controller is reduced and the performance of the tractive system is increased.

1. INTRODUCTION

Electric vehicles (EVs), as an effective alternative solution to alleviate the environmental problem caused by automobile exhaust, has become an important development orientation of vehicles[1]. But the limitations in power train and its service life are still the dominating barriers for their development. The temperature of the power train has great impact on its performance and service life.

Controller performance directly affects the overall performance of an electric vehicle (EV). The controller heats up when operated under extreme load and hence, reducing the efficiency of the vehicle. As such, EV propulsion system requires cooling systems, not only to the controller but also to the battery banks in order to ensure efficient operation and maximizing the electric components and vehicle lifetime.

Thermal discharge of electric drivetrain components results in heating of components. This could potentially lead to overheating. To avoid overheating, a cooling system is used to maintain the temperature within desirable limits.

To solve such overheating problems, there are several strategies such as air cooling, liquid cooling and phase changing material (PCM) cooling.

This work focuses on the design and development of a liquid cooling system for an electric vehicle's tractive system.

2. COMPONENTS USED

The following components are used in this work

- Solar panel
- Charge Controller
- Battery
- Pump
- Motor Controller
- Radiator
- Storage tank.

2.1 SOLAR PANEL

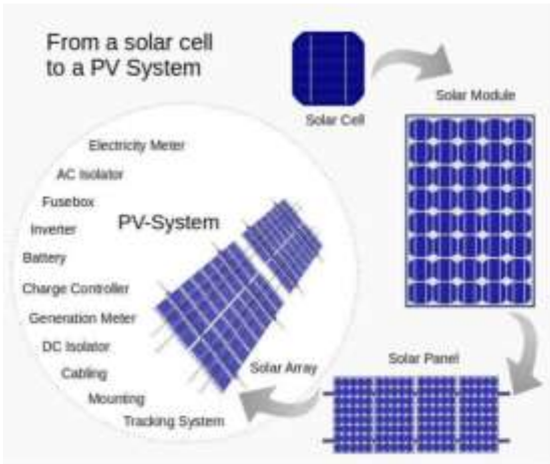


Fig 2.1 Solar Panel

Photovoltaic[2] modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells must be connected electrically in series, one to another.

A PV junction box is attached to the back of the solar panel and it is its output interface. Externally, most of photovoltaic modules use MC4 connectors type to facilitate easy weatherproof connections to the rest of the system. Also, USB power interface can be used.

Module electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability (amperes). The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

Solar panels also use metal frames consisting of racking components, brackets, reflector shapes, and troughs to better support the panel structure.

2.1.1 SOLAR CELL EFFICIENCY

Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 Watts (W). The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. There are a few commercially available solar modules that exceed efficiency of 24%.

- Efficiencies of solar panel can be calculated by MPP (maximum power point) value of solar panels
- Solar inverters convert the DC power to AC power by performing MPPT process: solar inverter samples the output Power (I-V curve) from the solar cell and applies the proper resistance (load) to solar cells to obtain maximum power.
- MPP (Maximum power point) of the solar panel consists of MPP voltage (V mpp) and MPP current (I mpp), it is a capacity of the solar panel and the higher value can make higher MPP.

2.1.2 CONNECTORS

Outdoor solar panels usually includes MC4 connectors. Automotive solar panels also can include car lighter and USB adapter. Indoor panels (including solar pv glasses, thin films and windows) can integrate microinverter (AC Solar panels).

2.1.3 LIMITATION

- Pollution and Energy in Production
- Impact on Electricity Network
- Implication onto Electricity Bill Management and Energy Investment

2.2 CHARGE CONTROLLER

A charge controller, charge regulator[3] or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

A solar charge controller[4] manages the power going into the battery bank from the solar array. It ensures that the deep cycle batteries are not overcharged during the day, and that the power doesn't run backwards to the solar panels overnight and drain the batteries. Some charge controllers are available with additional capabilities, like lighting and load control, but managing the power is its primary job.

2.2.1 STAND ALONE CHARGE CONTROLLER

Charge controllers are sold to consumers as separate devices, often in conjunction with solar or wind power generators, for uses such as RV, boat, and off-the-grid home battery storage systems. In solar applications, charge controllers may also be called solar regulators. Some charge controllers have additional features, such as a low voltage disconnect (LVD), a separate circuit which powers down the load when the batteries become overly discharged.

Simple charge controllers stop charging a battery when they exceed a set high voltage level, and re-enable charging when battery voltage drops back below that level. Pulse width modulation (PWM) and maximum power point tracker (MPPT) technologies are more electronically sophisticated, adjusting charging rates depending on the battery's level, to allow charging closer to its maximum capacity.

A charge controller with MPPT capability frees the system designer from closely matching available PV voltage to battery voltage. Considerable efficiency gains can be achieved, particularly when the PV array is located at some distance from the battery. By way of example, a 150 volt PV array connected to an MPPT charge controller can be used to charge a 24 or 48 volt battery. Higher array voltage means lower array current, so the savings in wiring costs can more than pay for the controller.

Charge controllers may also monitor battery temperature to prevent overheating. Some charge controller systems also display data, transmit data to remote displays, and data logging to track electric flow over time.

2.2.2 INTEGRATED CHARGE CONTROLLER CIRCUITRY

Circuitry that functions as a charge regulator controller may consist of several electrical components, or may be encapsulated in a single microchip, an integrated circuit (IC) .

2.3 BATTERY

A battery is a device consisting of one or more electrochemical cells with external connections provides power. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy.

2.3.1 TYPES OF BATTERY

Batteries are classified into primary and secondary forms:

- Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless.
- Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times.

2.4 PUMP

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. When a casing contains only one revolving impeller, it is called a single-stage pump. When a casing contains two or more revolving impellers, it is called a double- or multi-stage pump.

IN THIS WORK WE USES THE ROTARY POSITIVE DISPLACEMENT PUMPS

Rotary pumps move fluid using a rotating mechanism that creates a vacuum that captures and draws in the liquid. These pumps are very efficient because they can handle highly viscous fluids with higher flow rates as viscosity increases.

2.4.1 PUMPING POWER

The power imparted into a fluid increases the energy of the fluid per unit volume. Thus the power relationship is between the conversion of the mechanical energy of the pump mechanism and the fluid elements within the pump. In general, this is governed by a series of simultaneous differential equations, known as the Navier–Stokes equations. However a more simple equation relating only the different energies in the fluid, known as Bernoulli's equation can be used. Hence the power, P, required by the pump:

$$P = \frac{\Delta p Q}{\eta}$$

where Δp is the change in total pressure between the inlet and outlet (in Pa), and Q, the volume flow-rate of the fluid is given in m3/s. The total pressure may have gravitational, static pressure and kinetic energy components; i.e. energy is distributed between change in the fluid's gravitational potential energy (going up or down hill), change in velocity, or change in static pressure. η is the pump efficiency, and may be given by the manufacturer's information, such as in the form of a pump curve, and is typically derived from either fluid dynamics simulation (i.e. solutions to the Navier–Stokes for the particular pump geometry), or by testing. The efficiency of the pump depends upon the pump's configuration and operating conditions (such as rotational speed, fluid density and viscosity etc.)

$$\Delta P = \frac{(v_2^2 - v_1^2)}{2} + \Delta z g + \frac{\Delta p_{static}}{\rho}$$

For a typical "pumping" configuration, the work is imparted on the fluid, and is thus positive. For the fluid imparting the work on the pump (i.e. a turbine), the work is negative. Power required to drive the pump is determined by dividing the output power by the pump efficiency. Furthermore, this definition encompasses pumps with no moving parts, such as a siphon.

2.4.2 PUMP EFFICIENCY

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Pump efficiencies tend to decline over time due to wear (e.g. increasing clearances as impellers reduce in size).

2.5 MOTOR CONTROLLER

Kelly’s programmable motor controllers provide efficient, smooth and quiet controls for electric motorcycles, golf carts and go-carts, as well as industrial motor control. It is mainly supposed to solve noise problems of BLDC motor driving application. The KLS-D motor[5] controller must be based on hall sensors type. KLS-D controller cannot support sensor less brushless motor for now.

Compared to the traditional trapezoidal waveform control technology, this technique is based on sinusoidal wave driving technology to reduce the operation noise and 1/3 switching loss. This meets the noise reduction and efficiency requirements in the application of DC brushless motor.

It uses high power MOSFET's and, SVPWM and FOC to achieve efficiencies of up to 99% in most cases. A powerful microprocessor brings in comprehensive and precise control to the controllers. It also allows users to adjust parameters, conduct tests, and obtain diagnostic information quickly and easily. People can program the KLS controller on PC software and Android App.

2.5.1 STANDARD WIRING OF KLS-D CONTROLLER

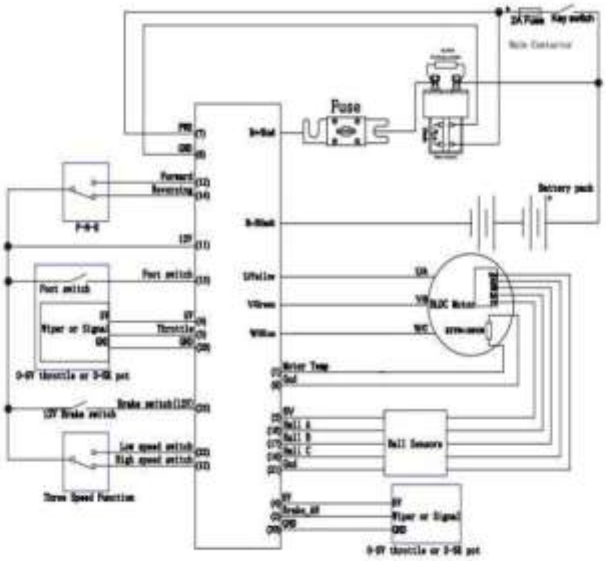


Fig 2.5.1 Standard wiring of kls-d controller

2.6 RADIATOR

Radiators are heat exchangers[6] used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling. Despite the name, most radiators transfer the bulk of their heat via convection instead of thermal radiation.

2.6.1 RADIATOR CONFIGURATION

The radiator configuration refers to the number of times the water must pass through the radiator core[7]. A single pass, or standard cross flow radiator, is a radiator configuration that allows the water to pass through the core once. A serpentine cross flow, or multipass radiator, allows the water to pass through the core multiple times.

The crossflow radiator is the traditional radiator configuration, since it is typically cheaper to manufacture. One should note that this type of heat exchange must transfer heat from the heat source (engine) to the water and

Then to atmospheric air. If one of the heat transfer rates to one of the fluids is smaller than the other, then one side of the system will limit the overall system performance. For example, a system in which the heat exchanger has a small air flow rate, but an infinite water flow rate, will be limited by the maximum heat transfer of the water to the air. A simple analogy to this would be a fluidic pipe system where one pipe is much smaller than all the others. This would result in a bottleneck and limit the flow.

A multi pass radiator is often considered for cooling systems that are air side limited. This is because the water must remain in the core for a longer period of time and will transfer heat to the air for a greater period of time. However, the pressure drop in the system increases for a multi pass radiator. Consequently, for a fixed water pump, a multi pass radiator would have a lower water flow rate than a single pass radiator.

Using a single pass radiator as a baseline reference, a double pass radiator increases the pressure drop by 16 times and a triple pass radiator increases the pressure drop by 64 times15.

2.7 STORAGE TANK

Storage tanks are containers that hold liquids, compressed gases (gas tank; or "pressure vessel", which is not typically labelled or regulated as a storage tank) or mediums used for the short- or long-term storage of heat or cold. The storage tank can be used for reservoirs.

2.7.1 TYPES OF TANK

ATMOSPHERIC

An atmospheric tank is a container for holding a liquid at atmospheric pressure. The major design code for welded atmospheric tanks are API 650 and API 620. API 653 is used for analysis of in-service storage tanks.

HIGH PRESSURE

In the case of a liquefied gas such as hydrogen or chlorine, or a compressed gas such as compressed natural gas or MAPP, the storage tank must be made to withstand the sometimes immense pressures exerted by the contents.

THERMAL STORAGE TANKS

One form of seasonal thermal energy storage (STES) is the use of large surface water tanks that are insulated and then covered with earth berms to enable the year-round of solar-thermal heat that is collected primarily in the summer for all-year heating. A related technology has become widespread in Danish district heating systems. The thermal storage medium is gravel and water in large, shallow, lined pits that are covered with insulation, soil and grass.

3. WORKING PRINCIPLE

This process works under the following principles:

- Second Law of Thermodynamics
- Newtons Law of Cooling

3.1 SECOND LAW OF THERMODYNAMICS

The second law of thermodynamics states that the total entropy of an isolated system can never decrease over time. The total entropy of a system and its surroundings can remain constant in ideal cases where the system is in thermodynamic equilibrium, or is undergoing a (fictive) reversible process. In all processes that occur, including spontaneous processes, the total entropy of the system and its surroundings increases and the process is irreversible in the thermodynamic sense.

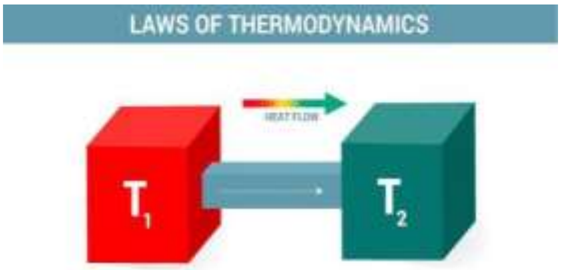


Fig 3.1 Second law of thermodynamics

3.2 NEWTONS LAW OF COOLING

Newton's law of cooling states that the rate of heat loss of a body is directly proportional to the difference in the temperatures between the body and its surroundings provided the temperature difference is small and the nature of radiating surface remains same. As such, it is equivalent to a statement that the heat transfer coefficient, which mediates between heat losses and temperature differences, is a constant.

This condition is generally true in thermal conduction (where it is guaranteed by Fourier's law), but it is often only approximately true in conditions of convective heat transfer, where a number of physical processes make effective heat transfer coefficients somewhat dependent on temperature differences.

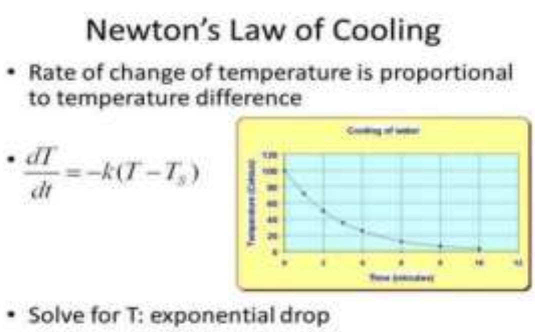


Fig 3.2 Newtons law of cooling

4.COOLING METHODS

Cooling is the transfer of thermal energy[8] from a hot medium. These cooling methods ensures that the process do not cause equipment or components to overheat. Many cooling applications use liquids as a medium to absorb heat rather than air or any other gases.

4.1 ACTIVE COOLING

An active cooling system is one that involves the use of an energy to reduce the temperature. Such systems circulates coolant to transfer heat from one place to another. The coolant is either a gas, such as in air cooling of computers, or a liquid such as in a car engine. In the latter case, liquid is pumped to transfer heat from the engine to the radiator, which in turn is cooled by passing air over it. Other active cooling systems make use of a refrigeration cycle.

4.2 PASSIVE COOLING

Passive cooling is an approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption. This approach works either by preventing heat from entering the interior (heat gain prevention) or by removing heat from the natural cooling.

4.3 PHASE-CHANGING MATERIAL

A phase changing material (PCM) is a substance with a high heat of fusion, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa.

4.4 TYPES OF COOLING SYSTEM

- Once-Through Cooling System
- Closed Recirculating System
- Open Recirculating System

4.4.1 ONCE-THROUGH COOLING SYSTEM

In once-through cooling, water is pumped from a nearby source, and passes only once through the system to absorb process heat[9]. It is then discharged back into the original source.

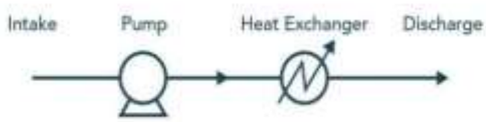


Fig 5.1 Once-through cooling system

Average Temperature Change: 5-10° F (3-6° C)
Amount of Water Used: High
Examples:

- Potable Water Systems
- Process Water
- General Service

4.4.2 CLOSED RECIRCULATING SYSTEM

In closed recirculating systems or dry cooling towers, heat absorbed by the cooling water is either transferred to a second coolant, or released into the atmosphere. The word dry is used because the water is never exposed to the air, and as a result, very little water is lost. An automobile engine is a good example of a closed cooling system.

Evaporation is not used in closed recirculating cooling towers. Instead, cool air rushes over a series of small tubes containing circulating coolant. Heat is transferred from the hot liquid inside the tubes to the cool air, resulting in cooling. The coolant is then returned back into the engine.

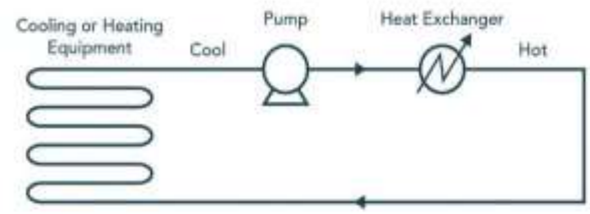


Fig 4.2 Closed recirculating system

Average Temperature Change: 10-15° F (6-8° C)

Amount of Water Used: Negligible Examples:

- Automobile Radiator
- Chilled Water Systems
- Food Temperature Controllers

4.4.3 OPEN RECIRCULATING SYSTEM

Open recirculating cooling systems or wet cooling towers are the most widely used designs in industry. Just as in closed recirculating systems, the open system uses the same water over and over again. Its most visible feature is the large, outdoor cooling tower that uses evaporation to release heat from the cooling water. Due to the mechanism, this type of cooling tower is also called an evaporative cooling tower. This system consists of three main pieces of equipment: the recirculating water pump(s), the heat exchanger(s), and the cooling tower.

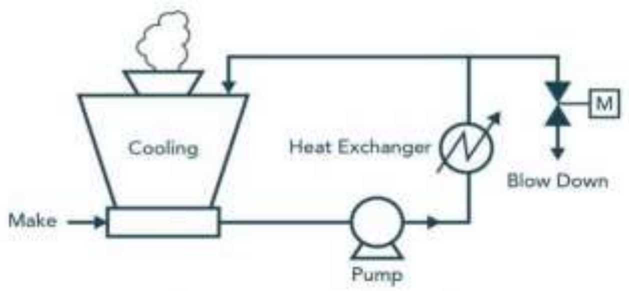


Fig 4.3 Open recirculating system

Average Temperature Change: 10-30° F (6-17° C)

Amount of Water Used: Moderate

Examples:

- Cooling Towers
- Spray Ponds

5. PROBLEM INDENTIFICATION

KELLY CONTROLLER APP

It also allows users to adjust parameters, conduct tests, and obtain diagnostic information quickly and easily. People can program the KLS controller on PC software and Android App.

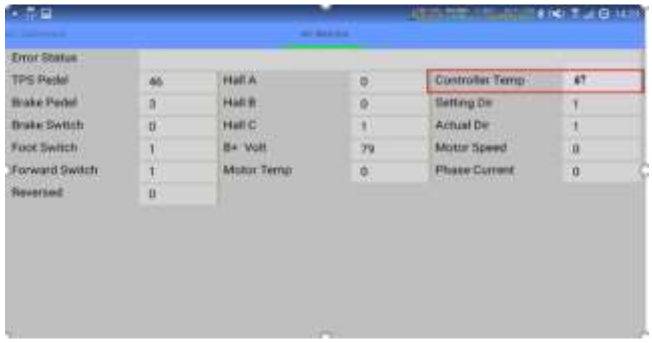


Fig 5.1 Kelly controller module

6. TECHNOLOGIES

6.1 EVALUATION OF DIFFERENT TECHNOLOGIES

6.1.1 FORCED-AIR SYSTEM

Forced-air cooling system with a simple structure has the advantage of high reliability[10] and low cost as well as easy maintenance, while it has poor thermal management, i.e. beyond operating temperature, uneven uniformity of temperature distribution and spread of thermal runaway.

In high ambient temperatures e.g. 45°C-50°C, the temperature inside the motor controller exceeds 55°C which is beyond the operating temperature and will result in thermal runaway. The uniformity of temperature distribution is also crucial due to the effect of degradation and cycle life. If one ignores the ambient temperature, the difference between cells is 2°C at the discharge current 2C-rate, and 4.8°C at the discharge current 6.67C-rate.

The uniformity of temperature distribution is also affected by the flow rate. As the flow rate increase, cell maximum temperature difference will increase, e.g. 3K at Re=136 and 4.8K at Re=1347. With the increasing flow rate, the cell maximum temperature difference can be even over 5K. It will give rise to degradation and the decrease of cycle life because the heat transfer between cells is quicker than the heat transfer from motor controller to air. So if one cell fails, thermal runaway will spread over the motor controller.

The following Table 6.1 shows that at the same flow rate the air volume is much bigger than the water volume, while the air heat transfer co-efficient is much lower than water heat co-efficient. So for air cooling to dissipate heat as much as water cooling, it requires higher volumetric flow rate which means more space and more power. Air cooling system takes up larger space and consumes much more energy comparing to liquid cooling system.

	Volumetric flow rate(L/s)	Average heat transfer coefficient (W/m²K)
Air	43	25
Mineral Oil	0.057	57
Water	0.049	390

Table 6.1 The volumetric flow rate and average heat transfer co-efficient

6.1.2 LIQUID SYSTEM

There are three types of cooling systems[11], namely passive cooling system, active cooling system, and refrigerant cooling system. The passive cooling system is affected by the ambient temperature, because the heat dissipation is dependent on the radiator and the radiator dissipates heat through the temperature difference between liquid and the ambient temperature.

Under normal circumstances, it works well, but under high ambient temperature it is insufficient. Active cooling systems have good thermal performance which can keep the motor controller within the operating temperature and keep temperature distribution between cells even because of high heat co-efficient of the coolant. Due to many auxiliaries and moving parts, the structure is complicated and difficult to maintain. It also has the tendency of leaking out. Compared to active cooling systems, direct refrigerant cooling systems are more efficient because they use refrigerant directly to cool the system instead of using refrigerant to cool coolant first and then using coolant to cool the system.

6.1.3 PCM SYSTEM

PCM cooling systems perform well on thermal management[12]. Even under high ambient temperatures from 45°C to 50°C, the temperature inside the cell is always below 55°C because of high thermal conductivity and latent heat.

Table 6.2 shows the characteristics of PCMs. In the case of stressful situations e.g. at current discharge rate 6.67C-rate and ambient temperatures of 45°C, the cell maximum temperature difference doesn't exceed 0.5K. And at normal conditions the difference of temperature between cells is negligible. If one cell fails, thermal runaway will not propagate because the PCM-graphite matrix absorbs and spreads the heat quickly.

The weakness of PCM is that it is more suitable for cold conditions or in space. When the temperature of the battery pack is higher than the temperature of the PCM melting point, heat is stored as latent heat and will be released to the module of battery when the ambient temperature is lower than the temperature of the PCM melting point.

The structure of PCM without new components is simple, light and space-saving. But it still has the potential of flammability and electrical conductivity as well as volume change due to the characteristic of the PCM-graphite.

	Density(g/cm³)	Latent heat(J/g)	Heat conductivity(W/(mK))
PCM(L)	0.79	173.6/266	0.167
PCM(S)	0.916		0.346

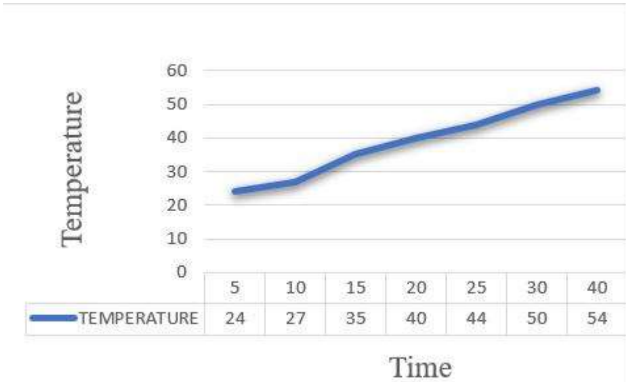
Table 6.2 The thermal characteristics of PCM

7. RESULTS

7.1 TEMERATURE VS TIME GRAPH

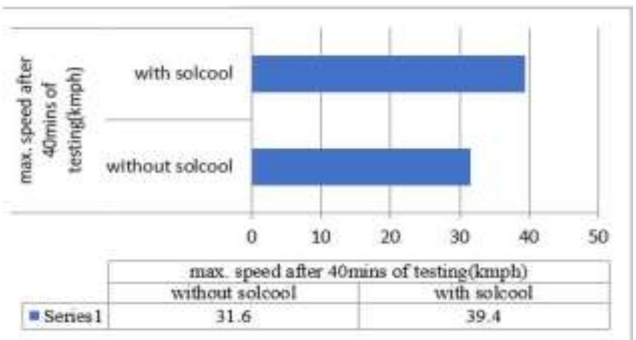
7.1.1 WIHOUT SOLCOOL

7.1.2 WITH SOLCOOL

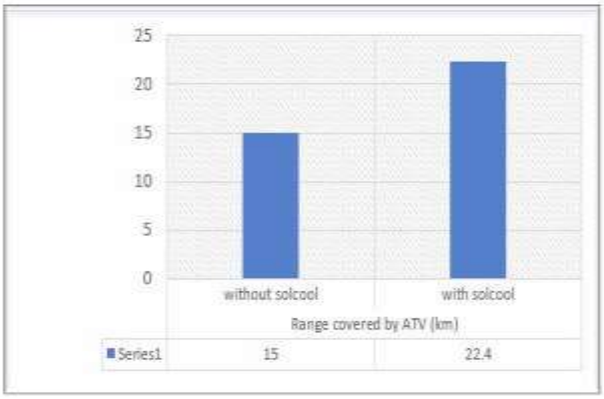


7.2 PERFORMANCE GRAPH

7.2.1 SPEED COMPARISON GRAPH



7.2.2 RANGE COMPARISON GRAPH



8. CONCLUSION

This work deals with solar powered cooling system for electrical vehicle. The major problem is overheating of the tractive system which affects the performance and lifetime of the vehicle. Thus, this work would tend to increase the performance and lifetime of powertrain system. By using water as the heat transfer medium, it was easy to carry the heat from the tractive system. After various iterations it was found that the discharge time of the battery was increased from 3.2 hours to 5 hours. Also, the heat transfer rate was increased to a considerable amount such that the temperature of the controller is maintained within 65°C for more than 70 minutes of testing. Therefore, we can conclude that this SOL-COOL can perform effectively and increase the performance of the tractive system.

9. REFERENCE

1. B. Otmar and G. Guenter, " Systems for hybrid cars," J. Power Sources 127, 8–15 (2004).

2. W.-S.Chang C.-C.Wang C.-C.Shieh, "Design and performance of a solar-powered heating and cooling system using silica gel/water adsorption chiller" Applied Thermal Engineering, Volume 29, Issue 10, July 2009, Pages 2100-2105.

3. Kalogirou, S.A. Solar thermal collectors and applications. Prog. Energy Combust. Sci. 2004, 30, 231–295.

4. Cao, Mengjia, "Thermal And Cooling Systems Modelling Of Powertrain For A Plug -In Parallel-Through-The-Road Hybrid Electric Vehicle" (2014). Wayne State University Theses. 290.

5. Kelly KLS-D Brushless Motor Controller User's Manual

6. Huiming Zou, Bin Jianga,, Qian Wang, Changqin Tian, Yuying Yana,"Performance analysis of a heat pump air conditioning system coupling with battery cooling for electric vehicles"(2014).

7. Chao Zhou, Yajuan Guo, Wei Huang, Haitao Jiang, Liwei Wu "Research on Heat Dissipation of Electric Vehicle Based on Safety Architecture Optimization" (2011).

8. T A Weustenfeld, W Bauer-kugelmann, J C Menken and K Strasser audi AG, Germany "Heat flow rate based thermal management for electric vehicles using a secondary loop heating and cooling system" (2013).

9. Camelia Stanciu, Dorin Stanciu and Adina-Teodora Gheorghian "Thermal Analysis of a Solar Powered Absorption Cooling System with Fully Mixed Thermal Storage at Startup" (2016).

10. A. Enthaler, T. A. Weustenfeld, F. Gauterin and J. Koehler, "Thermal management consumption and its effect on remaining range estimation of electric vehicles," IEEE 3rd International Conference on Connected Vehicles & Expo (ICCVE), 2014.

11. Kizilel, R., Sabbah, R., Selman, J. Robert & Al-hallaj, S., 2009. An alternative cooling system to enhance the safety of Li-ion battery packs. Journal of Power Sources, 194(2), pp. 1105-1112.

12. Z.Rao, SH.W. Experimental investigation on thermal management of electric vehicle battery with heat pipe. Energy Conversion and Management. 2013; 65:9297.