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## DEVELOPMENT OF CABIN THERMAL MANAGEMENT SYSTEM FOR AN ELECTRIC VEHICLE

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### Abstract:

Currently, electric vehicles are gradually increasing in their use to reduce the dependence on traditional sources. They have few moving parts that could be under maintenance and are also preferred for environmental reasons. When the Electric vehicle is in running condition, customers tend to focus on thermal comfort. Thermal comfort depends on the climatic conditions associated with winter, summer and rainy seasons. The vehicle is typically powered by an IC engine. As the engine runs, heat produced is used to warm the cabin or to provide air conditioning as per the passenger comfort needs. In an electric car, as heat produced by the motor is inadequate to keep the cabin warm, heaters must be installed. To provide air conditioning to chill the cabin, electric energy is drawn from the battery while it is operating. The quantity of electric energy is to be calculated to determine the range of the electric vehicle (EV). In the present work it is proposed to design a subsystem that would be able to control the function of cabin thermal management System for electric vehicle (EV). The main objective of cabin thermal management is to reduce the amount of energy used by the vehicle while maximizing passenger comfort. Mat lab Simulink tool will be used to design an auxiliary subsystem with the help of GANNET ENGINEERING PRIVATE LIMITED.

**Keywords:** EV, MATLAB, CTMS, Cabin, HVAC, Heating, AC.

## I. INTRODUCTION:

Electric vehicles' (EVs) rapid development and broad acceptance have been propelled by the growing global demand for environmentally friendly and sustainable transportation. Despite electric cars' many benefits, such as zero-emission propulsion and reduced dependence on nonrenewable fuel sources, a big challenge is the proper regulation of interior temperature conditions. Modern Cabin Thermal Monitoring Systems are essential for electric vehicles due to the unique characteristics of their powertrains and the need to keep power usage to a minimum. In the past, most automobiles with internal combustion engines relied on dedicated air conditioning systems and engine waste heat to maintain a comfortable interior temperature. Electric vehicles, which do not have internal combustion engines, must find innovative ways to provide a pleasant ride for its passengers without sacrificing efficiency or range. This study primarily focuses on developing a novel CTMS specifically for electric vehicles with the objective of overcoming this obstacle. In this objective is to develop a method that may reduce the electric cars overall energy usage while simultaneously optimizing the temperature inside the vehicle to ensure the comfort of the passengers. Improved temperature level control formulae, real-time environmental sensors, energy-efficient air conditioning systems, intelligent thermal insulation materials, and other critical components have been the focus of CTMS advancements. Additionally, the research delves into the practicality of utilizing solar panels and other renewable energy sources to power the CTMS and enhance its sustainability. In order to accomplish the overarching goal of making electric vehicles more appealing and useful to consumers, this research study is essential. Electric vehicles are more popular and more pleasant to drive when equipped with a reliable CTMS, which reduces the amount of electricity needed to maintain a reasonable interior temperature. As the automotive industry undergoes a dramatic shift towards long-term mobility, the creation of a trustworthy CTMS is crucial to allay consumer concerns about the practicality and efficiency of electric vehicles. In order to address a knowledge gap in the current literature, this project will use state-of-the-art technology and techniques, particularly MATLAB for modelling and simulation, to create a state-of-the-art Cabin Thermal management System for future electrical cars.

### Over view of research:

Most people in today's culture should aim to live comfortably regardless of their location. As of right now, one of the available modes of transportation is the electric automobile. It is necessary to regulate the temperature inside electric vehicles according to the requirements of the passengers. Range and battery life must be considered thoroughly when developing an electric vehicle's heat management system [1]. Various electric loads drain power from high voltage batteries, affecting electric vehicle range. These include vehicle weight, HVAC system, battery cooling system, and others. In India, the heat might sometimes need a sizable HVAC system, and to maintain the battery pack at an appropriate temperature, a chilled cooling system is also required. As a result, electric cars' HVAC systems are vital. An alternate option is offered that maintains the electric vehicle's high level of passenger comfort while enhancing its long range. The HVAC system's control is crucial to this project because it lessens the strain on the car's battery, which is responsible for maintaining a comfortable and safe temperature inside the vehicle. To do this, it must perform many essential functions, such as filtering the air, heating or cooling it, circulating the air, controlling the temperature, the speed of the fan, and entering reconstitution mode. To do this, one may use the MATLAB Simulink tool to build an auxiliary subsystem for the HVAC systems of electric vehicles. Multiple inputs and outputs are involved in controlling the heating and cooling system for electric automobiles that is located in the cabin. The data inputs to the HVAC system are processed by the processor to provide the necessary outputs.

## II METHODOLOGY

The introductory layout of the research study work is programmed in number 1 below. Check this out want to find out more about the proposed study. Intel central processing unit, air conditioning unit button, fan blower speed demand, cabin air temperature level, air conditioning system compressor rate requirement, heating unit condition, heating unit percentage demand, and blower rate need are the components that make up the schematic. It is possible to see the inputs and outputs of the micro controller in the block diagram shown below fig.no.1.

Controlling the air conditioning is essential for the comfort of passengers staying in electric cars. The following results should be processed by the micro controller: heating unit condition, blower speed need, A/C compressor condition, heating unit condition, and air conditioning compressor speed need. The following inputs should be provided by the traveler those are air conditioner switch position, cabin air temperature level, heating unit standing, heating unit portion need, and the status and speed demands of the air conditioner compressor.

### II .1 Proposed system model diagram.

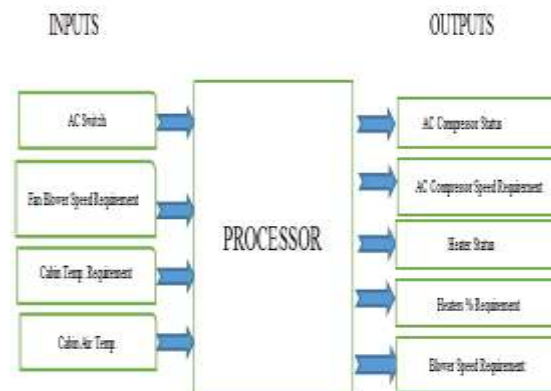


Fig.1. Proposed system model diagram.

### III.STEPS INVOLVED:

**Step one is developing an electric vehicle CTMS MATLAB Simulation:** Simulation is an integral part of the Cabin Thermal Management System's (CTMS) thorough preliminary design process. When engineers are outlining the specific requirements of the system, they consider factors like energy efficiency, passenger comfort, and the overall design of the electric car. Using design tools like MATLAB, the team develops mathematical models to simulate the thermal dynamics of the electric car's cabin. Models like this include environmental factors, thermal insulation, and HVAC system behavior through the use of simulation, engineers may test out several combinations of the CTMS's design and control schemes to see which ones work best in different driving situations.

**Building a Physical Prototype and Conducting Real-World Tests:** A physical model is built utilizing the most effective style configurations once the CTMS is substituted. The next stage is to test this prototype in a controlled laboratory environment to ensure it can handle a variety of conditions, including varying temperatures, speeds, and climates. What constitutes real-world testing is the integration of the CTMS with a real electric vehicle and the collection of data pertaining to the vehicle's performance under actual road conditions. Designers may then make small adjustments based on any discrepancies they uncover between the system's efficiency in simulation and the real world. The screening results alert changes to the control formula, a/c components, and system style overall to ensure the CTMS meets or exceeds the stated standards.

**Final Optimization and Integration of Renewable Energy Sources:** Verifying the primary function of the CTMS is the first step in investigating the possibility of using renewable energy sources, such as solar panels, to power system. To evaluate the efficacy and practicality of incorporating renewable energy sources into the thermal management system, MATLAB simulations are used once again. The last optimization step is to fine-tune the whole CTMS using the knowledge gathered from both simulations and real-world testing. This includes refining control algorithms for adaptive temperature level adjustment, increasing the effectiveness of the air conditioning system, and ensuring a seamless integration of the electric vehicle's main power source. The finished product is a robust and balanced cabin thermal management system that enhances the convenience of electric vehicle passengers while lowering power consumption.

**IV WORKING PRINCIPLE:****Fig.2. HVAC System Control Panel.**

Make sure everyone in the automobile is safe and comfortable is the job of the HVAC system. Its many vital functions include air filtration, temperature regulation, blood circulation, de-fogging, thawing, temperature management, and follower speed control, to name a few. Manages the temperature and directs the airflow with the help of the setting choice. The airflow may be directed to various areas of the body, including the floor, the head, and the windscreen, using a system of doors that is also known as an air door. The air doors may be operated by electric servos, hoover servos, or wires.

**IV 1.Modes of air flow direction in an EV:**

| MODE | HEAD | FEET | W.S |
|------|------|------|-----|
| 1    | 1    | 0    | 0   |
| 2    | 0.5  | 0.5  | 0   |
| 3    | 0    | 1    | 0   |
| 4    | 0    | 0.5  | 0.5 |
| 5    | 0    | 0    | 1   |

Table 1. .Modes for air flow direction in an EV.

Table 1 illustrates the modes for air flow direction in an EV .In the above table, mode 1 indicates that air flows only through the head, the feet and ws empty. Mode 2 indicates that air flows both to the head and the feet simultaneously. the ws is empty and Mode 3 indicates that air flows only through the feet the head and ws are empty. Mode 4 indicates that air flows both through the feet and the ws. the head is empty finally, mode 5 indicates that air flows exclusively through the ws, the head and feet are empty.

## IV2. MATLAB MODEL DEVELOPMENT FOR AN HVAC SYSTEM:

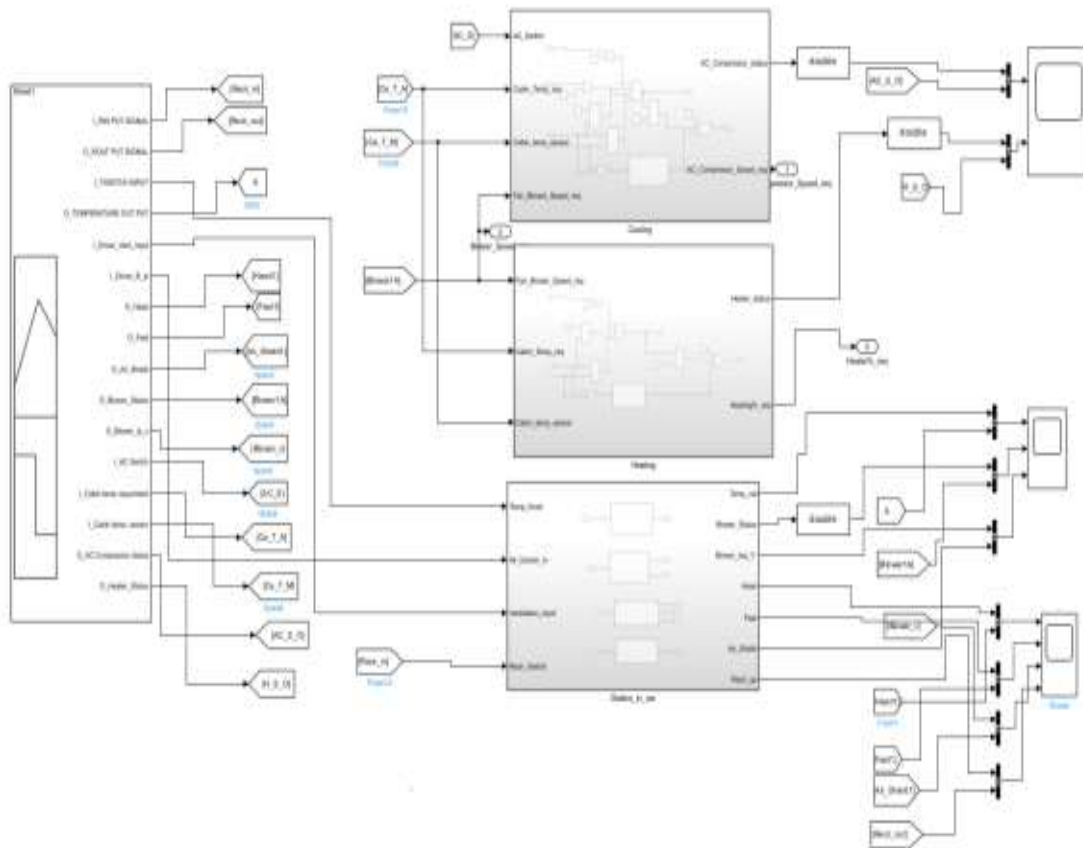


Fig.3. Simulink model for HVAC Control System in Electric car.

## IV3. Cooling System Logic:

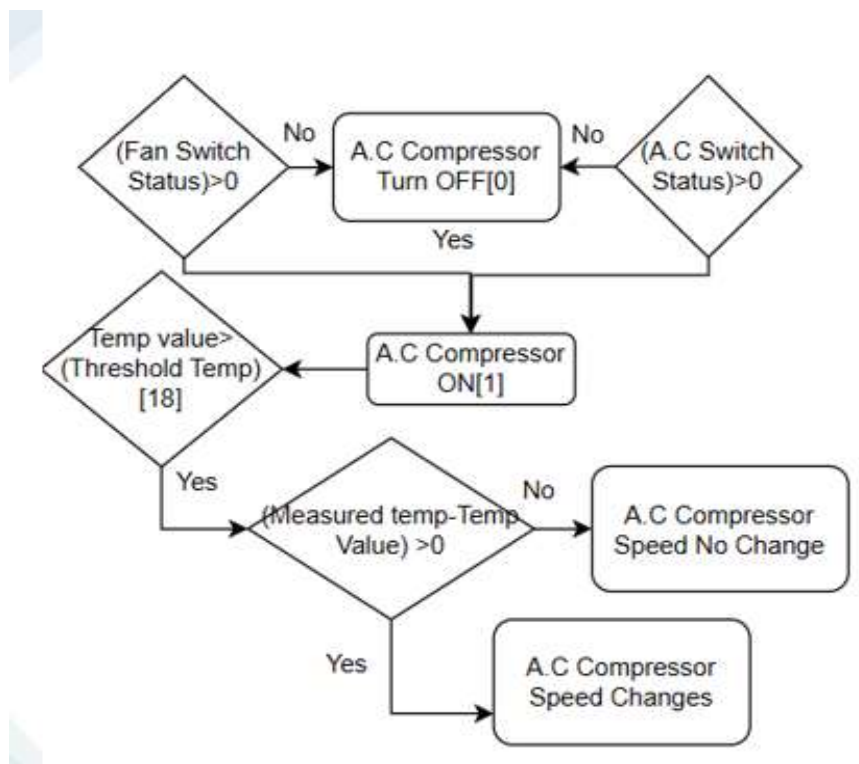


Fig.4 Cooling System Logic.

### IV3. Heating system Logic:

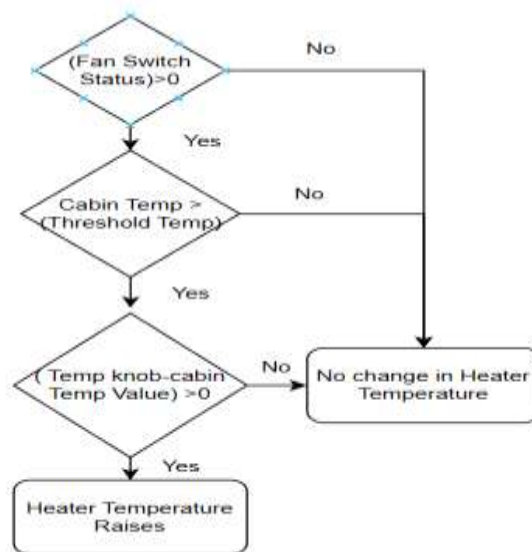


Fig.5 Heating System Logic.

### IV4. Heating Sub system for HVAC System in EV:

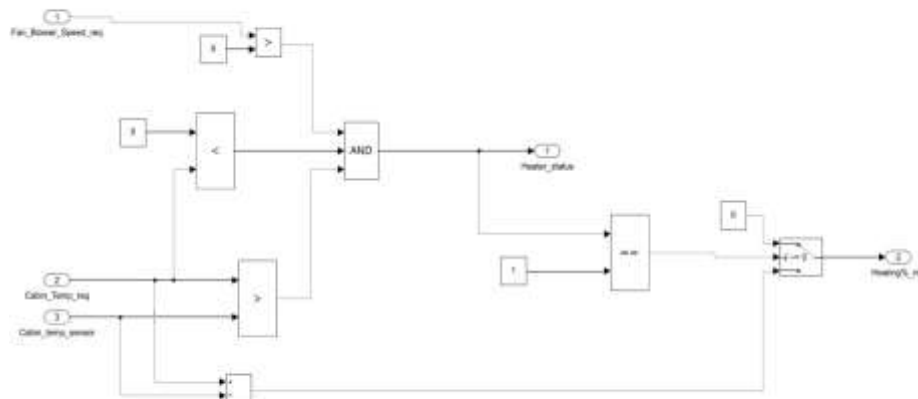


Fig.6 Heating Sub system (technique).

Figure 5 illustrates the Heating Sub-system utilized in the HVAC System of an electric vehicle. The heating subsystem of the cabin in an electric car is an essential component of the vehicle's thermal management system, ensuring passenger comfort during cold weather conditions.

**Electric Heater:** Most electric cars utilize electric heaters as the primary heating source for the cabin. These heaters work by passing an electric current through a resistive element, which generates heat. The warm air produced by the heater is then circulated throughout the cabin via the vehicle's HVAC (Heating, Ventilation, and Air Conditioning) system.

**Heat Pump:** Some electric vehicles incorporate heat pump technology into their heating subsystem. Heat pumps operate by transferring heat energy from the ambient air outside the vehicle to the interior. They are more energy-efficient than traditional electric heaters, especially in moderate climates, as they leverage the temperature differential between the inside and outside of the vehicle. This helps reduce the energy consumption of the

heating system and extends the vehicle's range.

**Thermal Management System:** Critical components have their temperatures monitored by a complex thermal management system, which is typically operated by an electronic control unit (ECU). In order to maximize cooling efficiency, the system adapts the coolant flow rate and fan speeds using the real-time data.

#### IV5. Cooling Sub system for HVAC System in EV:

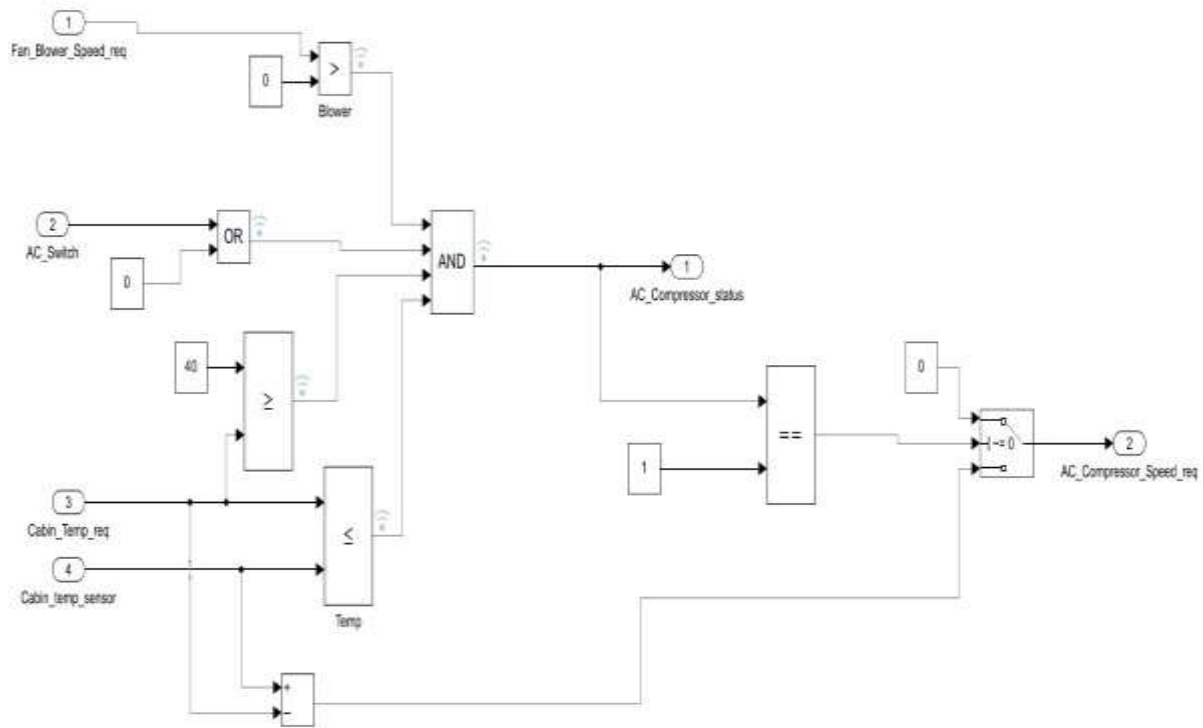


**Fig.7 Cooling Sub system (technique).**

Figure 6 illustrates the Cooling Sub-system utilized in the HVAC System of an electric vehicle. By regulating temperatures, an electric car's cooling subsystem ensures peak performance and prolongs the life of critical components. The temperature of the lithium-ion battery, an essential part of electric vehicles, is often controlled using liquid cooling systems that employ coolants that flow via intricate channels. The cooling subsystem not only drains heat that is produced during operation, but it also helps power electronics like motors and inverters stay efficient. Incorporating a dual function in thermal management, the cooling subsystem enhances passenger comfort and is an essential component of the cabin's HVAC system. Temperature sensors strategically placed throughout the vehicle continuously input real-time data to adaptive control algorithms, enabling dynamic adjustments in coolant flow rates and fan speeds. The electric car's performance and energy efficiency may be optimized by combining these technologies and maintaining it within specific temperature constraints.

**Thermal Management System:** Critical components have their temperatures monitored by a complex thermal management system, which is typically operated by an electronic control unit (ECU). In order to maximize cooling efficiency, the system adapts the coolant flow rate and fan speeds using the real-time data.

**Cabin Thermal Management:** Methods for Combining HVAC Units Common tasks performed by a cooling subsystem include integrating with the cabin's air conditioning system and cooling the power electronics and batteries. This connection will allow for improved management of the electric vehicle's whole temperature conditions, ensuring the comfort of passengers.

**Factors to Consider for Energy Efficiency:** An electric vehicle's entire driving range might be affected by the amount of electricity needed to cool it. This motivates engineers to develop efficient cooling systems that effectively regulate temperatures while minimizing energy use. Some state-of-the-art systems may also use the waste heat from the power electronics to warm the cabin, further reducing energy consumption in colder weather.

**Integrating Temperature Sensors:** In order to monitor the condition of critical components, electric cars are

equipped with temperature sensors that are strategically placed throughout. Because these sensors are transmitting data to the management system in real-time, this cooling subsystem can be fine-tuned quickly.

**Methods for Adaptive Control:** To adapt the cooling system's operation to driving conditions, environmental variables, and the battery's health, complex control algorithms typically built in MATLAB evaluate sensor data in real time. This adaptive control allows the cooling subsystem to respond to changing demands and environmental conditions.

## V RESULTS AND DISCUSSION:

### V.1 Head, Feet and Windshield air flow direction results:

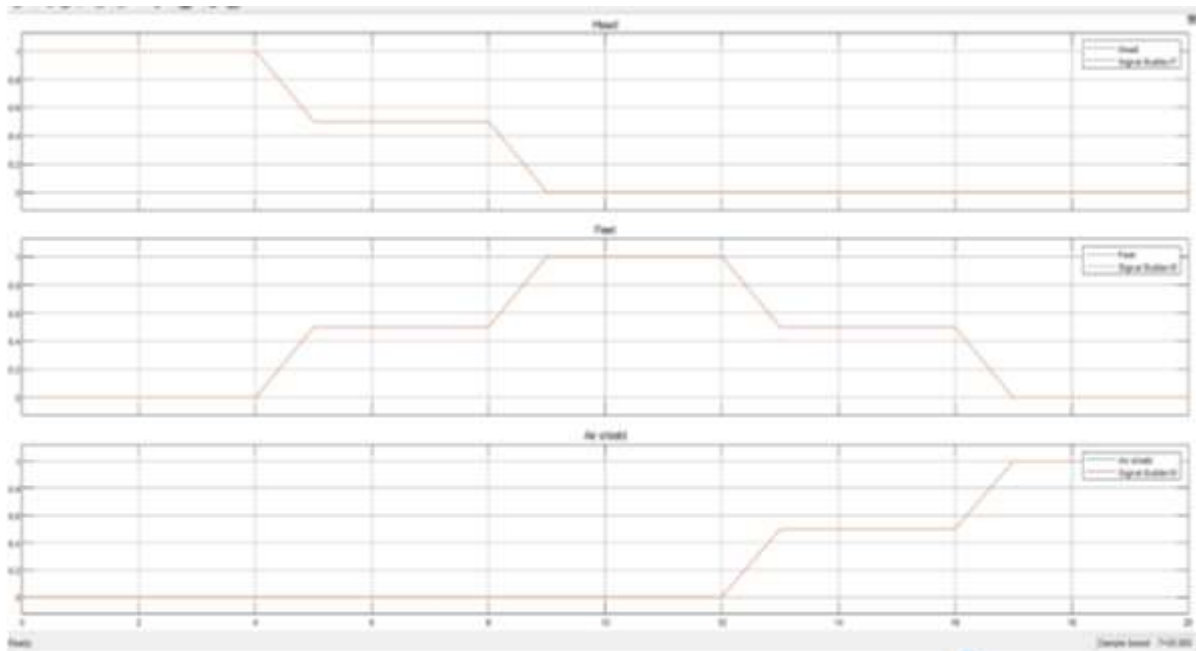


Fig.8 Head, Feet and Windshield air flow direction results.

### V.2 Input Data Results:

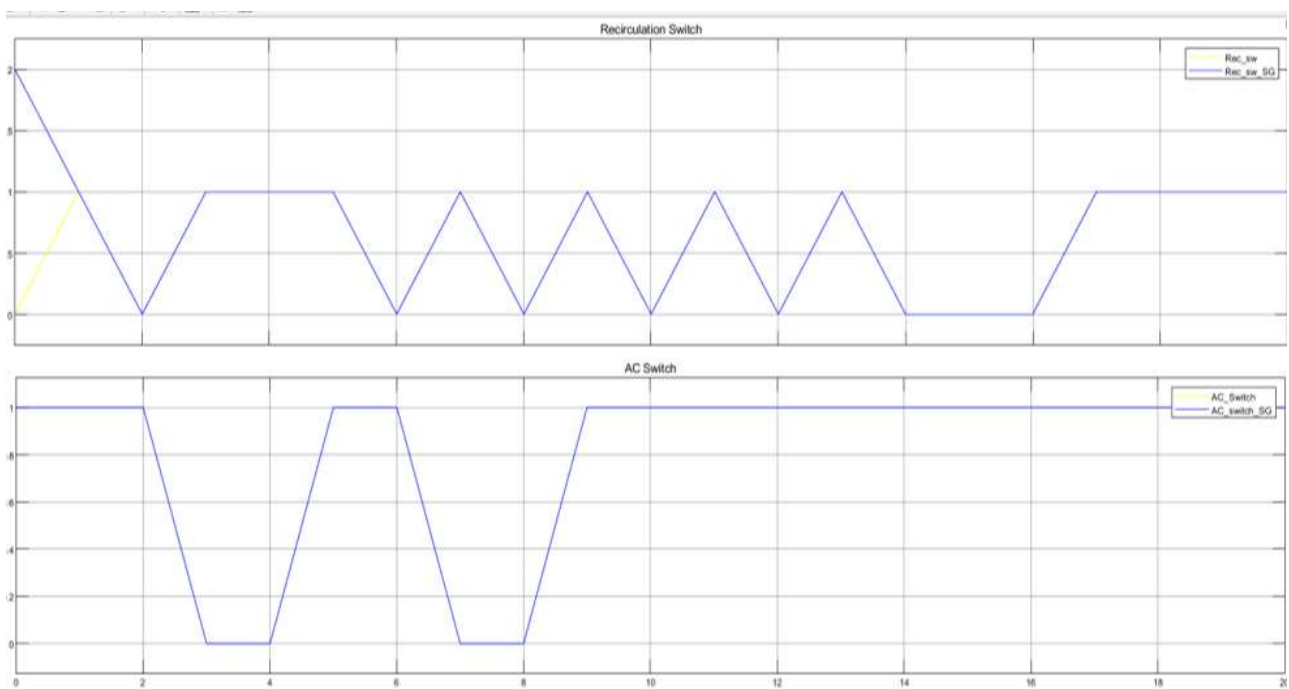
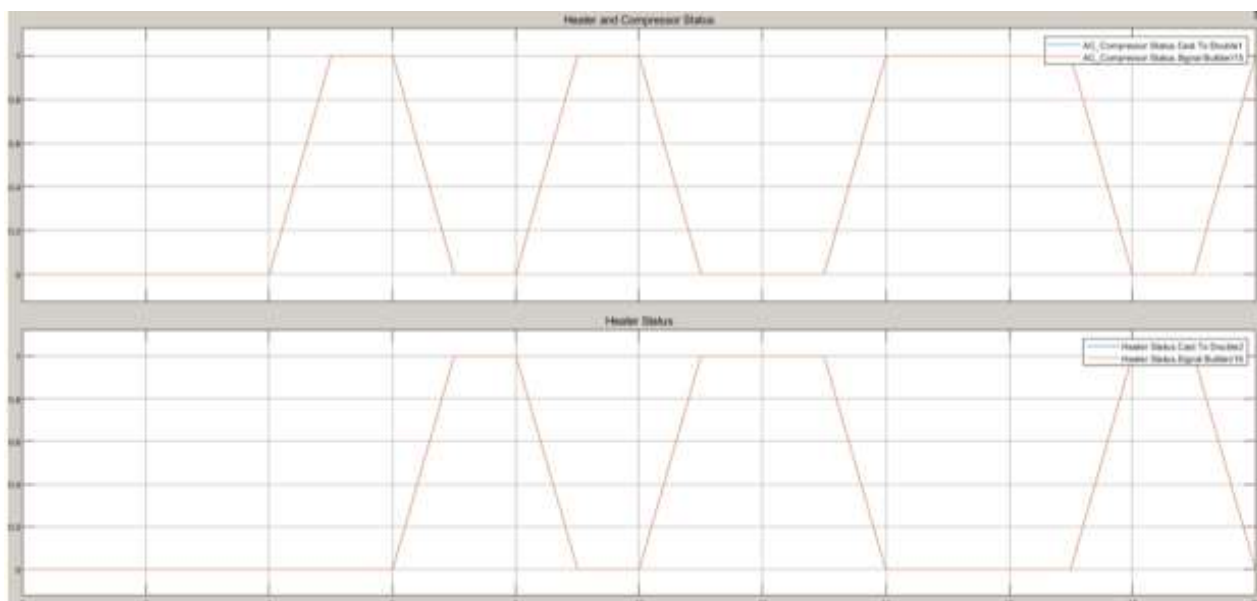


**Fig.9 Input data Results.****V.3 Outputs Results for Heater and AC Compressor status:****Fig.10.Signal Builder Output Results for Heater and AC Compressor status.****VI CONCLUSION:**

Lastly, a state-of-the-art Cabin Thermal Management System (CTMS) for electric cars has been developed, which is a significant step forward in enhancing the overall driving experience. The unique challenges faced by electric car interiors will be addressed by this technology. Through a systematic approach that included problem definition, literature review, and modelling, the study has laid the groundwork for a robust CTMS design. Making use of MATLAB for modelling, running simulations, and developing control algorithms allowed us to increase the system's efficiency. In keeping with the broader goals of sustainable transportation, the use of renewable energy sources such as solar panels enhances sustainability even further. The research led to the development of a CTMS that assures passenger comfort via adaptive temperature control while prioritizing energy economy. It lessens the effect on the electric vehicle's driving range. An iterative refining process including prototyping, real-world testing, and optimization has resulted in a comprehensive solution that bridges the gap between theoretical breakthroughs and practical implementation. The relevance of the developed CTMS in making electric vehicles more attractive, practical, and environmentally friendly is emphasized by its success. As a result, this helps with the bigger picture of moving towards more environmentally friendly and intelligent transportation choices, which is especially important given the rising popularity of electric cars.

**List of abbreviations**

EV: Electric Vehicle.

CTMS: Cabin Thermal Management System

HVAC: Heating ventilation and Air Conditioning

ECU: Electric Control Unit.

AC: Air Conditioning

WS: Wind shield

**DECLARATIONS****Availability of data and materials**

The corresponding author may provide the datasets used and/or analyzed for this study upon reasonable request, and the principal researchers may grant access to particular data.

**Competing interests**

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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**Authors' contributions**

CHAKALI SIRISHA was responsible for the concept, data gathering, investigation, methodology, and original draft writing. Process, supervision, and conceptualization were completed by P. Manjunath. Dr. Smt. G. Parvathi carried out the conceptualization, data collecting, investigation, writing revision, and editing. The completed work was read and approved by all writers.

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