Research on Intelligent Control Technology of Air Conditioning Systems for New Energy Vehicles

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Abstract. With the significant development of science and society at present, the relevant technologies of new energy vehicles are also constantly innovating. As an important component of vehicles, the air conditioning system should also keep up with its developing trend in terms of intelligent control technology, which can meet the reasonable requirements of users' environmentally friendly and comfortable sitting experience, as well as society's demand for energy conservation and efficiency improvement. This paper conducts research on key technologies of intelligent control systems for air conditioning of new energy vehicles. It covers four aspects: heat pump air conditioning technology; fuel cell waste heat utilization; electric compressor control technology; dedicated energy storage and system optimization. A new era of intelligent air conditioning control systems has been summarized to enhance the intelligence level of new energy vehicle air conditioning. The goal is to achieve energy conservation, and emission reduction and improve energy efficiency.

Keywords: New energy vehicles; Intelligent control technology; Air conditioning system; Energy saving and efficiency improvement.

1. Introduction

Recently, there has been significant progress in global science and technology, and new energy vehicles such as hybrid power have been introduced and replaced one after another. The air conditioning system is a crucial component of vehicles, so it is necessary to keep pace with the development of automotive technology. This can meet the needs of users for comfort, energy efficiency and environmental performance. Compared to traditional fuel vehicles, the air conditioning system of new energy vehicles has higher technical and environmental requirements. Now it still faces a series of technical problems and challenges, such as low energy efficiency, low-temperature control accuracy and slow system response speed [1]. To catch up with the development of the times and overcome a series of difficulties, the research on intelligent control technology for air conditioning systems of new energy vehicles is reasonable and necessary.

The air conditioning compressor of current common new energy vehicles does not need to rely entirely on the power generated by brushless permanent magnet direct current motors. The actual effect of such air conditioning compressors in cooling and heating is not good enough and may also have a bad impact on the engine range of new energy vehicles. Based on this situation, most domestic automobile manufacturers choose to use batteries to directly power compressors. The range level of a car may also be affected by regional differences. In northern cities with low winter temperatures, electric vehicles can account for more than half of the overall energy consumption for heating [2]. In addition, Feng Quan built a model predictive controller for a thermal management system of an electric vehicle [3]. It can effectively reduce the energy consumption of the system by controlling the fan speed and water pump flow rate. To improve the energy efficiency of hybrid vehicles, Amini M R et al. designed a two-layer model predictive controller with a scheduling layer and a leading layer for the control of battery thermal management systems [4]. Li Guodi used an improved Particle Swarm Optimization algorithm to optimize the control strategy of the thermal air conditioning system, ensuring that the heat pump air conditioning system can also operate at its optimal state during the dynamic operation of the vehicle [5]. The main function of the current new energy vehicle air conditioning system is to provide a comfortable and safe driving environment by adjusting the

temperature and humidity inside the vehicles. It is beneficial to improve the overall cooling and heating effect of the system.

This paper focuses on the background and research status and conducts research on the air conditioning system of new energy vehicles: First, a brief overview of the composition and characteristics of the air conditioning system is provided. Then, the key technologies that serve it are introduced. In addition, the requirements for intelligent and advanced air conditioning control systems are shown. The final section contains relevant conclusions and prospects for the future. The paper is hoped to be helpful for the progress of new energy vehicle air conditioning systems and the development of social technology.

2. Main components and key technologies of air conditioning systems for new energy vehicles

2.1. Main Composition and Characteristics

The air conditioning system of new energy vehicles mainly consists of a compressor, condenser, evaporator, expansion valve, fan, control system, etc. To ensure the normal operation of the air conditioning system, each corresponding component equipment needs to perform its corresponding function and cooperate [1]. After years of development and upgrading, the air conditioning system of modern new cars has become more energy-efficient, environmentally friendly, and multifunctional. It is gradually approaching consumers' needs for comfort level and environmental friendliness. Cars may encounter bumpiness during driving, which can cause vibrations that can influence the air conditioning system, leading to loose pipelines, loose components or damage. Therefore, the air conditioning system of new energy vehicles not only needs to have strong impact resistance to ensure stable and reliable operation during driving but needs to have strong stability as well [6]. Especially in high or low-temperature environments, it can maintain normal operation and stable work. This way then puts forward higher requirements for the material selection, manufacturing process, and structural design of air conditioning systems [7]. All of them need more reliable technical support.

2.2. Application of Key Technologies in Air Conditioning Systems for New Energy Vehicles

The air conditioning system is an indispensable and important component of a car. It can not only provide the most basic cooling and heating functions but play a role in ventilation, air purification, humidity and airflow rate regulation as well. The following mainly discusses and analyses the application of key technologies in the field of new energy vehicles from four perspectives.

2.2.1. Heat pump air conditioning technology

Heat pump air conditioning technology is a key technology widely used in intelligent control systems for new energy vehicle air conditioning and is also the core technology for realizing cooling and heating functions. When a heat pump air conditioner is used for cooling and heating, the cooling solenoid valve, cooling electronic expansion valve, electronic solenoid valve, heating electronic expansion valve, etc. will be in different states, which will drive the compressor to perform different actions, ultimately achieving the purpose of cooling or heating [8]. In the actual operation of automotive air conditioning systems, there will be two regulation forms, both intelligent regulation and direct heat regulation lamps. The heat pump central air conditioning system technology for automobiles mainly uses heat pump technology to accomplish the heating effect on the interior of the car. In theory, the heat pump-type central air conditioning system can achieve a good intelligent efficiency ratio in practical use, which meets the constantly developing needs of the new energy vehicle industry [2].

When the external temperature is low, this technology maintains a comfortable temperature inside the car. During the process of releasing air from the interior of the vehicle, the process of discharging through the vehicle's doors and windows can effectively help defrost the doors and windows. Besides, using an air circulation control system to regulate the temperature inside the vehicle. With the help

of a heat pump air conditioning control system, temperature control can also be effectively carried out.

2.2.2. Fuel Cell Waste Heat Utilization

The relatively common air conditioning control system used in automobiles is the inhalation cooling air conditioning system, which can effectively and reasonably utilize the waste heat generated by fuel cells and scientifically regulate the temperature inside the car. Utilizing the waste heat of fuel cells to achieve cooling or heating of air conditioning through a displacement system during use matters a lot. The reasonable application of this technology can effectively reduce the energy consumption of air conditioning control systems and improve the endurance of cars, which gradually becoming widely used in temperature control systems inside new energy vehicles.

At present, there are mainly two living methods for waste heat recovery technology commonly used in new energy vehicle air conditioning systems [2]. One is the heat exchange between the high-temperature circuit based on the cooler and the low-temperature circuit of the battery, the other is the direct heat exchange between the high-temperature circuit and the low-temperature circuit of the battery. Usually, the waste heat recovery system consists of two parts: the electric drive control system and the battery pack thermal management system. The entire system includes forms of heat transfer such as convective exchange of coolant, heat exchange of radiators, and heating by thermistors. Also, it can heat the battery pack by exchanging the heat of the electric drive control system through the coolant under the action of the four-channel solenoid valve.

In cooling mode, waste heat can be used to assist in heating the evaporator of the absorption refrigeration system or drive the absorber of the refrigeration system. As for heating mode, waste heat can be used to heat the air inside the vehicle or the battery to improve the efficiency of the battery.

Utilizing waste heat to achieve cooling or heating in air conditioning systems can reduce the load on electric compressors. Traditional automotive air conditioning systems mainly rely on compressors to achieve cooling, and the operation of compressors requires a large amount of electrical energy, especially in high-temperature environments. To some extent, this process has a significant impact on battery range. Using the waste heat generated by fuel cell systems to supply air conditioning systems is equivalent to utilizing renewable energy. It can reduce dependence on fossil fuels, and therefore be more environmentally friendly [9].

2.2.3. Electric compressor control system

The previous section mentioned that waste heat utilization can reduce the load on electric compressors, which is also part of the development and innovation of electric compressors in the new era. The new electric compressor control system can achieve efficient cooling and heating of new energy vehicle air conditioning systems through intelligent control and power supply, improving the comfort level inside the vehicle while optimizing energy utilization efficiency.

Compared to traditional models, sensors of the air conditioning system can also be used to obtain sensing information for adjustment and control. By obtaining relevant data through sensors, the control unit can understand the real-time status of the interior and exterior environment of the vehicle, and then determine the operating mode, operating time, and output power of the compressor. In this way, the operation of the compressor can be intelligently adjusted according to actual needs, avoiding unnecessary energy waste and improving energy utilization efficiency [10].

The electric compressor control system can be integrated with the vehicle's power battery system for application. As the energy core of new energy vehicles, the power battery system can provide power for the electric compressor and adjust the power output of the compressor in real time through the control unit to meet the needs of the vehicle's air conditioning system. In addition, the electric compressor control system can also use intelligent energy-saving control strategies. Take automatically turning off the compressor when the vehicle stops as a typical example, it is to improve the energy efficiency of the air conditioning system and extend the range of the power battery. To achieve intelligent control of electric compressors, it is necessary to build corresponding software

and hardware systems. The final goal is to intelligently drive and control the operation of the compressor according to the actual situation.

2.2.4. Dedicated energy storage and system optimization

The solar energy storage system is not limited by the power supply of the grid, it has a certain independent power supply function. As a dedicated energy storage for air conditioning, it can also cope with emergencies such as power outages [11]. A solar energy harvesting system, including solar photovoltaic panels, is used to convert solar energy into direct current. The energy storage system operates through lithium metal battery packs. It stores the excess electricity generated by solar photovoltaic panels for use during the electricity consumption peak in downtown [12].

The inverter is the core equipment that converts DC electrical energy into AC electrical energy. It can regulate and smooth electrical energy to provide stable power output. The control system is the brain of the entire solar air conditioning system, which monitors and controls its constituent parts through sensors and controllers to implement automatic regulation of solar energy collection, energy storage, and energy output. It adjusts the working mode of the system based on real-time solar energy supply, system power status, and user demand to gain optimal energy utilization efficiency.

To effectively control energy consumption, the air conditioning system can use a control method that combines zero load control with virtual model intelligent control. Zero load control technology uses intelligent technology to analyses the user's body heat and generate body temperature data. Based on this, precise control of temperature and humidity is carried out. The operation principle of zero load control technology is to test the relationship between the human body and the microenvironment. It obtains the heat loss value of the human body in the microenvironment and then regulates the microenvironment based on the heat loss value of the human body. This approach keeps a balance between human body heat and the microenvironment, reducing the consumption of ineffective energy [13].

Zero load forecasting technology can meet the optimal air conditioning environment demand of users, reduce the load on human body temperature regulation, and control this value to zero. An intelligent control scheme with energy-saving computer virtual models can be selected for precise control. By issuing corresponding control instructions through the device management layer, energy-saving control goals can be accomplished. This control mode considers both internal and external environmental factors of the vehicle, which can more accurately reproduce the actual operating status of the air conditioning. Thus, precise control of the actual operating status can be realized, ensuring that the air conditioning system is in the optimal operating state. This can fully ensure the user's comfort level while minimizing energy consumption to the maximum extent possible.

3. Optimization of Air Conditioning Control System for New Energy Vehicles

Compared to traditional fuel vehicles, the air conditioning control system of new energy vehicles has been optimized in structure. It has added components such as a blower, temperature sensor, air conditioning controller, evaporator, and expansion valve. Intelligent devices such as air conditioning thermal comfort system, electric drive cooling system, large screen host cooling system, water replenishment and exhaust system have also been added. In daily applications, it can help cool the interior space of the car and perform heating treatment. In the heating function, heating electric, heating tubes and Positive Temperature Coefficient functions are mainly used [2].

The intelligent air conditioning control system can use temperature sensors inside and outside the car to monitor real-time temperature changes inside and outside the car. Then adjust the air conditioning cooling and heating modes accordingly to achieve a comfortable in-car environment. At the same time, it can also be combined with humidity sensors to achieve intelligent control of indoor humidity and provide more comfortable air quality [1]. Take its variable frequency regulation effect as a typical example, it can keep the indoor temperature fluctuation range within -1 to 0.5 ℃ of the target value, far exceeding the traditional regulation efficiency. With a figure of almost 5 ℃.

In addition, the current version of the product generally also has an air evolution device, which can decompose organic matter, destroy pollutants, and better adapt to the requirements of the consumers.

The intelligent air conditioning control system can intelligently adjust according to the driving status of the vehicle. When the vehicle is driving at high speed, the system can automatically adjust the opening degree and wind speed of the air conditioning vents to maintain a comfortable interior environment and reduce energy consumption. As for driving or parking at low speeds, the system can make corresponding adjustments to minimize energy consumption. The system can be combined with the vehicle's energy supply situation, such as battery status and charging status. This approach can maximize energy consumption savings and extend vehicle range.

From the above, conducting energy-saving and intelligent control of air conditioning systems can timely and accurately respond to changes and make corresponding optimizations [14]. To achieve optimal control of air conditioning, research on reasonable prediction of end load demand. Adjust the working status of the air conditioning system according to the load, to implement optimized energy-saving control of centralized precision air conditioning.

4. Conclusion

In the new era, new energy vehicles have broad development space and bright prospects. This paper is based on papers published in journals related to new energy vehicles, reviewing the relevant technologies and corresponding achievements in the intelligent control of air conditioning in recent years. With the gradual development trend of intelligence and energy conservation in the new energy vehicle industry, it is particularly crucial to make use of relevant technological achievements and effective conclusions to promote the intelligent control and management of the air conditioning system. The heat pump air conditioning system can mainly achieve practical functions such as cooling and heating of the air conditioning and power battery. Fuel cell waste heat utilization technology repeatedly utilizes excess energy during the waste heat conversion stage, which can improve the energy efficiency of automobiles to some extent. The innovation of electric compressor control technology lies in the elimination of the front-end drive wheel and a separate control module, which facilitates automation and intelligent control. The dedicated energy storage and optimization system can accurately obtain indoor and outdoor temperature information and analyze and model the collected weather data. Besides, it can use machine learning algorithms to predict future temperature trends and make corresponding adjustments.

As new energy vehicles will become an important part of energy conservation, emission reduction, and energy efficiency improvement strategy proposals, it is expected to overcome increasing technical challenges related to charging and battery life in the following days. The development trend will be to continuously increase the proportion of high-grade renewable energy and improve the efficiency of resource utilization. As an important component of vehicle energy consumption, the air conditioning system of new energy vehicles must adapt to this trend.

In the future research and development process, emphasis should be placed on the integrated design of new energy vehicle batteries and intelligent air conditioning systems based on existing foundations. At the same time, the introduction of new "variable displacement control" technology will effectively improve the automation level of the air conditioning control system for new energy vehicles. In this way, the vehicle battery can fully utilize the energy generated during the energy consumption process under normal operation. This further achieves energy conservation and consumption reduction in the automotive air conditioning control system, thereby improving the range performance of new energy vehicles.

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