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БАЯНДАМАЛАР ЖИНАҒЫ**

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ЭНЕРГЕТИКИ: ПУТИ ИХ ИННОВАЦИОННОГО РЕШЕНИЯ»**

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### **IMPROVING THE EFFICIENCY OF ELECTRIC MOTORS OF TRANSPORT VEHICLES UNDER LOW-TEMPERATURE CONDITIONS**

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Abstract. This paper investigates the optimization of electric vehicle (EV) powertrain efficiency in harsh climatic conditions, with a focus on the integration of heat pump systems. The study analyzes the primary challenges of operating electric motors at low temperatures and proposes solutions aimed at minimizing energy consumption for thermal management. The prospects for implementing advanced thermal regulation technologies in the transport sector of Kazakhstan are evaluated, contributing to increased vehicle range and overall system sustainability.

Keywords: electric motors, low-temperature efficiency, heat pump, energy saving, transport vehicles.

Modern transportation systems require the implementation of advanced technologies to improve the efficiency of electric vehicles. One of the most significant problems in the industry remains the decline in powertrain performance at low temperatures, which increases energy consumption, reduces the effective driving range, and places additional stress on the vehicle's electrical infrastructure.

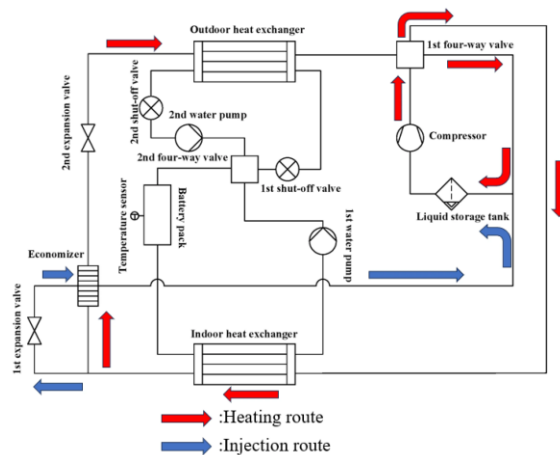


Figure 1 — Battery thermal management coupled with vapor injection heat pump AC.

### 1. Introduction

The global shift toward sustainable transport has highlighted a critical vulnerability in electric vehicle (EV) technology: performance degradation in extreme cold. Modern transport sectors require significant improvements in energy saving to remain viable in northern latitudes. One of the most significant problems remains the decline in performance, which leads to a reduction in effective driving range and places additional stress on the local electrical infrastructure.

In regions such as Kazakhstan or Northern Europe, temperatures frequently drop below  $-20^{\circ}\text{C}$ . At these levels, the energy required just to maintain the battery's chemical stability and provide cabin comfort can consume up to 40-50% of the total stored energy. This article examines how optimizing the interaction between the electric motor and the thermal management system can mitigate these losses.

### 2. Analysis of Low-Temperature Impact on Powertrains

The operation of electric motors and battery systems under low-temperature conditions introduces several physical and chemical inefficiencies:

- **Increased Internal Resistance:** At low temperatures, the lithium ions in the battery move more slowly through the electrolyte, increasing internal resistance and decreasing the available power output.
- **Viscosity in Mechanical Components:** The lubricants within the reduction gear and motor bearings thicken, leading to higher friction losses during the initial stages of operation.
- **Waste Heat Scarcity:** Unlike internal combustion engines (ICE), electric motors are highly efficient and produce very little waste heat. While this is usually an advantage, in cold weather, there is no "free" heat available for the cabin, forcing the system to use battery energy for resistive heating.

### 3. Thermal Management and the Heat Pump Cycle

A primary focus of this study is the transition from traditional PTC (Positive Temperature Coefficient) heaters to integrated heat pump systems.

#### 3.1. The Heat Pump Mechanism

A heat pump works by moving thermal energy from a cold space to a warm space using a refrigeration cycle. The efficiency is measured by the *Coefficient of Performance (COP)*. In

an EV context, the system can extract heat from the ambient air or the motor itself to warm the battery and cabin.

### 3.2. Integration with the Electric Motor

The electric motor and inverter are liquid-cooled. In a traditional setup, this heat is dissipated into the atmosphere. However, in an optimized system, this "waste" energy is captured by a heat exchanger and fed into the heat pump's evaporator. This "Battery-coupled evaporator" system (Figure 1) allows the battery to act as a thermal reservoir.

### 4. Advanced Technologies: The Octovalve System

A major breakthrough in thermal management is the Octovalve technology (Pat. US10569620B2). The Octovalve serves as a centralized hub that can reconfigure the flow of coolant between different loops:

1. Motor Loop: Collects heat from the motor and power electronics.
2. Battery Loop: Either heats or cools the battery cells to maintain an optimal 20°C to 30°C range.
3. Cabin Loop: Provides passenger comfort.

By using a four-way or eight-way valve system, the vehicle can "borrow" heat from the motor to warm the battery before a charge, or use the battery's thermal mass to store heat generated during high-speed driving for later use.

### 5. Discussion of Results

Research indicates that using a heat pump combined with intelligent thermal regulation significantly reduces the "energy penalty" of cold weather.

- Range Extension: Systems utilizing the Octovalve and heat pump have shown a 15-20% increase in range at -10°C compared to EVs using only resistive heating.
- Charging Efficiency: By pre-heating the battery using recovered motor heat, DC fast-charging times are reduced by up to 30% in winter conditions.
- Sustainability: Reducing the energy load for heating directly contributes to the overall sustainability of the transport sector.

### 6. Conclusion

Improving the efficiency of electric motors in cold climates requires a holistic approach to thermal management. The integration of heat pumps and centralized valves like the Octovalve allows for the recycling of thermal energy that was previously wasted. Future research should focus on the use of low-GWP (Global Warming Potential) refrigerants and AI-driven predictive thermal control to further optimize energy consumption in extreme environments.

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