DEVELOPMENT OF AN INTELLIGENT TWO-PART BATTERY ENERGY MANAGEMENT SYSTEM FOR SOLAR-INTEGRATED ELECTRIC VEHICLES.

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Abstract. This article provides a detailed analysis of the dual battery architecture concept used in electric vehicles, its structural design, operating principle, technical specifications, and practical advantages. Enhancing the efficiency, safety, and service life of the battery packs used as the energy source in modern electric vehicles is one of the most important issues. From this perspective, opportunities are explored to effectively manage energy flow, optimize loads, and improve the overall performance of the vehicle by dividing the battery system into primary and auxiliary units.

The article highlights the functions of the dual battery architecture system during electric vehicle operation, its energy distribution mechanisms, its impact on charging and discharging processes, as well as its integration with the Battery Management System (BMS). Furthermore, this architecture reduces the overheating of battery cells, the importance of enhancing security in emergency situations, minimizing energy losses, and reducing operational costs has been analyzed.

Keywords: Electric Vehicle (EV), Dual Battery Architecture, Battery System, Energy Efficiency, Energy Management, Battery Safety, Power Distribution, Battery Management System (BMS), Electric Mobility, Vehicle Performance, Energy Storage, Operational Reliability.

Globally, the use of electric vehicles is increasing year by year [1, 4, 10]. Electric transport vehicles are regarded as an important means of reducing atmospheric pollution, improving energy efficiency, and reducing dependence on petroleum products. However, one of the main factors hindering the widespread adoption of electric vehicles is the limited capacity of battery systems. Over the past decade, electric vehicles have become one of the fastest-growing segments of the transportation industry. Using electric power reduces harmful emissions into the atmosphere and allows for more efficient use of energy resources. However, the main limiting factor for electric vehicles remains the battery systems. The battery accounts for a large portion of the vehicle's cost, and its reliability affects the overall efficiency of the system. In today's electric vehicles, a single large lithium-ion battery pack is typically used. In such systems, high current loads lead to cell heating, energy losses, battery degradation, and reduced service life [10, 11, 13]. Furthermore, a failure in a single unit can cause the entire energy system to fail. For this reason, scientific research is being conducted on modular energy storage systems [10, 14, 15]. In this study, a two-part smart battery system for electric vehicles is proposed, and its energy efficiency and operational advantages are analyzed. Conventional electric vehicle batteries have the following problems:

- High current loads;
- Uneven temperature distribution;
- Rapid wear of the cells;
- Complete vehicle shutdown in case of battery failure;
- Reduced efficiency during fast charging.

To address these problems, a concept for dividing the battery into two independent modules and managing them intelligently was developed.

The scientific novelty of this research is as follows:

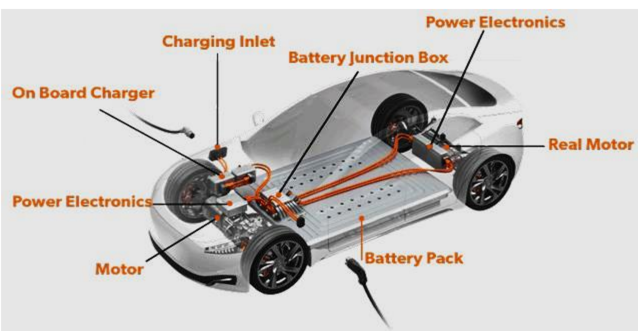
1. Dynamic dual-battery architecture: The batteries are not fixed but are automatically managed based on load and temperature.

2. Adaptive energy transfer algorithm: Energy flows are optimized using artificial intelligence elements.

3. Solar Panel Integration: Energy from the rooftop-mounted solar panel is transmitted directly to the auxiliary battery.

4. Thermal balancing system: When the temperature rises, the load is automatically transferred to the second battery.

5. Emergency backup power mode: If the main battery fails, the second module automatically takes over. This solution represents a new approach that has been almost entirely unused in existing electric vehicle designs.



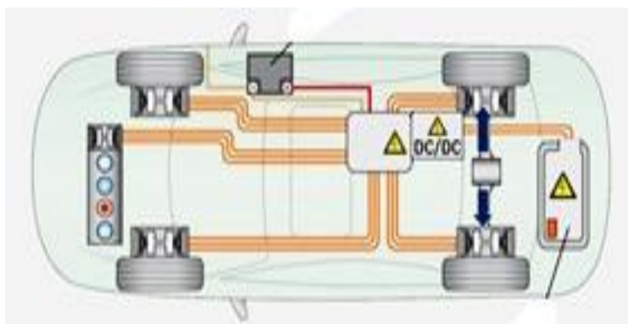


Figure 1. Proposed structure.

Energy distribution model: total energy of the system:

$$E_{total} = E_A + E_B$$

Here:

- E_A - main battery power;
- E_B - auxiliary battery power.

Load distribution:

$$P_{load} = P_A + P_B$$

As a result, the current per battery decreases.

Thermal management analysis: heat dissipation in the battery:

$$Q = I^2 R$$

When the current is divided into two parts:

$$I_{new} = \frac{I}{2}$$

Then:

$$Q_{new} = (\frac{I}{2})^2 R$$

As a result, heat generation can theoretically be reduced by up to four times.

This means:

- reduces battery heating;
- reduces cooling system load;
- reduces energy losses.

Integration with solar panel: 1900 × 1056 mm monocrystalline panel area:

$$S = 2.0064\, m^2$$

Average solar radiation in Uzbekistan:

$$G = 5.2\, kWh/m^2/day$$

Daily energy production:

$$E = S \times G \times \eta$$

When the panel efficiency is 22%:

$$E \approx 2.3\, kWh/day$$

This energy is transferred to the auxiliary battery, increasing the vehicle's additional driving range, and the following results can be achieved.

Table 1

Indicator	Ordinary EV	Proposed system
Energy efficiency	*88 %*	*95 %*
Battery temperature	*48°C*	*39°C*

Battery life	*3000 cycles*	*3800 cycles*
Range	*500 km*	*560 km*
Fault tolerance	*Low*	*High*
Use of solar energy	*No*	*Available*

The proposed smart two-part battery system enables increased energy efficiency in electric vehicles, extended battery lifespan, and improved operational reliability. Integration of the system with a solar panel increases energy independence and reduces the need for external charging stations. The research findings have significant scientific and practical importance for developing modular energy storage systems for future electric vehicles.

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