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11th International Conference on Renewable Electrical Power Sources

PROCEEDINGS

Editor Dr Milica Vlahović

Belgrade, November 02-03, 2023

P R O C E E D I N G S

11th International Conference
on Renewable Electrical Power Sources

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on Renewable Electrical Power Sources

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President to the Society
for Renewable Electrical
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within the SMEITS
Prof. dr Zoran Lazarević

Editor
Dr Milica Vlahović

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FOREWORD

The conditions created by the development of technologies in which modern man lives have led to a complex and paradoxical effect: that by removing obstacles on the way to a more comfortable, simpler, faster and more efficient life and way of working, man also generates numerous misfortunes, attracting dark clouds of threats to the survival of the planet and humanity. The question that concerns and affects all of us - all people, all living beings, systems in which life takes place, large and small, strong and weak - boils down to the problem of the negative impact of man on the environment; this issue invites us to an urgent solution by looking at the causes, proposing solutions, evaluating them, changing approaches and ways of thinking, as well as drawing correct conclusions. Simply put, by adapting nature to one's own needs, man threatens and damages it. That is why, with the joint efforts of all of us, individuals, organizations and states, it is necessary to take all possible measures to immediately prevent the negative effects that are ahead of us.

The importance of renewable sources of electricity, which this international conference focuses on, is noticeable from two angles: the first - it is certain that fossil fuels as a resource will disappear and it is necessary to find alternative sources, the second - the use of renewable energy sources by its essence implies "clean" technology that significantly contributes to reducing CO_2 *emissions and thus mitigating climate change and reducing pollution, while encouraging social and economic development in all spheres of life.*

The 11th International Conference on Renewable Electrical Power Sources is organized by the Society for Renewable Electrical Power Sources (DOIEE) at SMEITS, with co-organizers: The Institute of Architecture and Urban & Spatial Planning of Serbia (IAUS) and the Chamber of Commerce and Industry of Serbia, with the support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

The registered participants designed their papers according to the given conference topics:
- *Energy sources and energy storage;*
- *Energy efficiency in the context of use of renewable energy sources (RES);*
- *Environment, sustainability and policy;*
- *Applications and services.*

Eminent authors - scientists, teachers, experts in this field from fifteen different countries: Algeria, Belgium, Bosnia and Herzegovina, China, Croatia, Greece, Hungary, India, Portugal, Saudi Arabia, Serbia, Slovenia, Spain, the United Arab Emirates, and Ukraine, contributed to the conference through sixty-nine papers that were reviewed by the Scientific Committee of the Conference, and after the review process were accepted for presentation at the conference and for publication in the proceedings.

At the end of this short message and at the beginning of the proceedings I believe that it can be proudly said that scientists, researchers, policy makers and industry experts gathered in one place, in order to exchange experiences and knowledge with the aim of promoting scientific and professional ideas and results of research, technology improvement for the use of RES, promoting the rational use of electricity, affirming and proposing inventive solutions in the field of sustainable sources of electricity.

Belgrade, *Milica Vlahović*
November 2023

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<u>Energetska efikasnost u kontekstu primene RES:</u>

<u>Životna sredina, održivost i politika:</u>

Aplikacije:

ENERGETSKA EFIKASNOST U ELEKTRIČNIM VOZILIMA – PREGLED

ENERGY EFFICIENCY IN ELECTRIC VEHICLES – AN OVERWIEW

Zoran STEVIC*,
University of Belgrade, Technical Faculty in Bor, School of Electrical Engineering

Ilija RADOVANOVIC,
University of Belgrade, Innovation Center of the School of Electrical Engineering,
School of Electrical Engineering

Predrag STOLIĆ,
University of Belgrade, Technical Faculty in Bor

Sanja PETRONIC,
Institute of General and Physical Chemistry, Belgrade

Marko JARIC,
University of Belgrade, Innovation Center of the Faculty of Mechanical Engineering

Misa STEVIC,
Elsys Eastern Europe, Belgrade

Dejan ILIC,
Freelancer, Belgrade

e-mail: zstevic@tfbor.bg.ac.rs (*Correspondence)

Apstrakt

Ovaj rad se bavi istraživanjem i analizom energetske efikasnosti kod električnih vozila. U kontekstu sve veće popularnosti električnih vozila kao održive alternative tradicionalnim vozilima sa unutrašnjim sagorevanjem, postaje ključno razumeti i unaprediti njihovu efikasnost. Razmotreni su faktori koji utiču na efikasnost, uključujući aerodinamičnost, masu vozila, efikasnost električnog pogona i baterije, kao i uticaj eksternih faktora poput rute vožnje i brzine. Zatim su analizirani rezultati istraživanja kako bi se utvrdili ključni faktori koji mogu povećati efikasnost električnih vozila, kao što su optimizacija aerodinamike, smanjenje mase vozila i vraćanje energije kočenja, koji mogu značajno poboljšati energetsku efikasnost. Takođe su istraženi i različiti načini optimizacije električnog pogona i baterija kako bi se smanjio gubitak energije tokom vožnje.

***Ključnereči:** električno vozilo, baterija, energetska efikasnost*

Abstract

This paper deals with research and analysis of energy efficiency in electric vehicles. In the context of the increasing popularity of electric vehicles as a viable alternative to traditional internal combustion vehicles, it becomes crucial to understand and improve their efficiency Factors affecting efficiency are considered, including aerodynamics, vehicle mass, electric drive and battery efficiency, as well as the influence of external factors such as route driving and speed. The research results were then analyzed in order to determine the key factors that can increase the efficiency of electric vehicles, such as optimizing aerodynamics, reducing vehicle mass and recovering braking energy, which can significantly improve energy efficiency. Different ways of optimizing the electric drive and batteries were also investigated in order to reduce energy loss during driving.

***Key words:**electrical vehicle, battery, energy efficiency*

1 Introduction

An important segment in the development of electric vehicles are the possibilities for increasing the energy efficiency of electric vehicles, in terms of saving energy accumulated in the vehicle itself and increasing the performance range of the car with the given initial resources. Some of the possibilities that should provide such a progress nowadays are: using energy under braking; using waste heat energy; additional supply by solar cells and airflow turbine; improved mechanical energy transmission system; improved cars shell design; increasing of power convertors efficiency; special design of electric engines; using supercapacitors, fuel cells and new generation batteries; route selection on the criterion of minimum consumption in real time; parameter monitoring inside and outside of the vehicle and computerized system control with optimization of energy consumption [1,2]. Many cars are designed to use only electricity as motive power, which reduces emissions to zero. The solar roof is a fine example, so the development of city cars is moving towards the prototype of fully solar vehicles. A solar vehicle is an electric vehicle that is powered entirely or substantially by direct solar energy [2,3].

Another concept that has been developing over the years is a kinetic energy recovery system, often known simply as KERS. KERS is an automotive system for recovering a moving vehicle's kinetic energy under braking. The recovered energy is stored in a reservoir (for example a flywheel or a battery or supercapacitor) for later use under acceleration. Electrical systems use a motor-generator incorporated in the car’s transmission which converts mechanical energy into electrical energy and vice versa. Once the energy has been harnessed, it is stored in a battery and released when required. The mechanical KERS system utilizes flywheel technology to recover and store a moving vehicle’s kinetic energy which is otherwise wasted when the vehicle is decelerated. Compared to the alternative of electrical-battery systems, the mechanical KERS system provides a significantly more compact, efficient, lighter and environmentally-friendly solution. There is one other option available - hydraulic KERS, where braking energy is used to accumulate hydraulic pressure which is then sent to the wheels when required. Development of new components, improved connections and electric engine control algorithms allow increase of efficiency of power convertors, therefore electric engine itself, to the maximum theoretical limits. New generation improvements of electric engine system has an impact on price, however investment quickly pays off during operating. Major efforts are invested in the development of high energy density batteries with minimum equivalent serial resistance (ESR). Also, current research show that fuel cells have reached needed performances for commercial use in electric vehicles. Supercapacitors that provide high power density increase the acceleration of vehicle as well as collecting all the energy from instant braking, therefore improvements of the characteristics of power supply are made [1,3-5].

Increasing the energy efficiency of an electric vehicle implies striving to increase the efficiency of each of the key elements of the vehicle (Figure 1) [6].

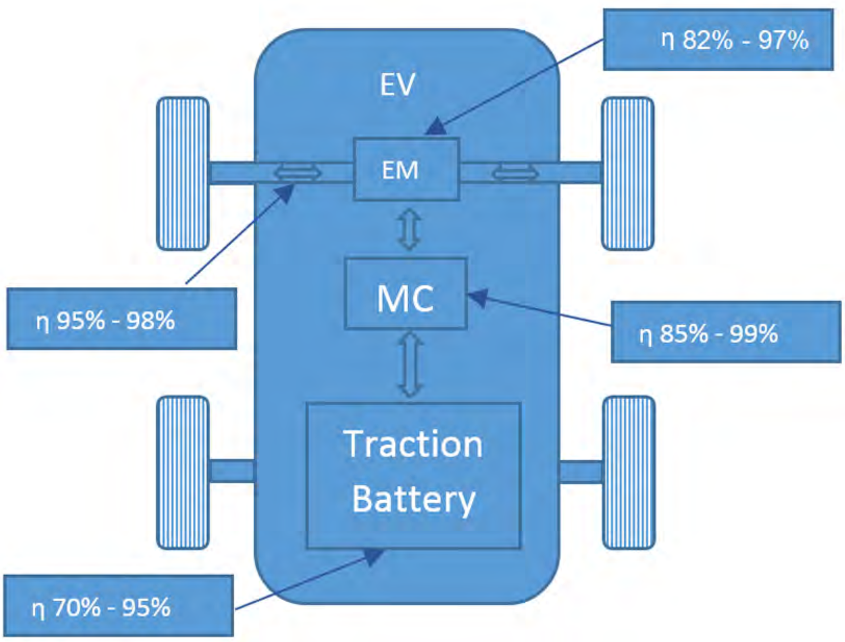

Fig. 1 Energy efficiency of each of the key elements of the EV [6]

Modern electric vehicles have full information system that has constant modifications and does monitoring of inside and outside parameters in order to achieve maximum energy savings. Except for smart sensors, it is highly important to process GPS signals and route selection on the criterion of minimum energy consumption. By combining these technologies, concepts and their improvements, we are slowly going towards energy-efficient vehicles which will greatly simplify our lives in the future [1,7].

2 Reduction of electrical losses in EVs

Increasing the energy efficiency of converters can be achieved by optimizing them configuration and control, as well as the selection of adequate components. Converter configuration depends on the type of electric motor, possible regenerative braking energy, drive dynamics, etc. [1].

The main task of electric vehicle development is certainly optimization power supply. In addition to the usual combinations (batteries and supercapacitors), research is moving towards new systems that integrate advantageous characteristics of previously used systems.

Typically, standard supercapacitors can only store about 5% as much energy as lithium-ion batteries. The new hybrid system can store about twice as much as standard ultracapacitors, but this is still much less than standard lithium-ion batteries. However, the advantages supercapacitors are that they can capture and release energy in seconds, providing a lot faster charging times compared to lithium-ion batteries, as well as full utilization of braking energy. In addition, traditional lithium-ion batteries can only be recharged a few hundred times, which is much less than 20,000 cycles which is provided by the hybrid system [1, 8].

A fuel cell electric vehicle (FCEV) has higher efficiency and lower emissions compared with the internal combustion engine vehicles. But, the fuel cell has a slow dynamic response. Therefore, a secondary power source is needed during start up and transient conditions. Supercapacitor can be used as secondary power source. By using supercapacitor as the secondary power source of the FCEV, the performance and efficiency of the overall system can be improved. In this system, there is a boost converter, which steps up the fuel cell voltage, and a bidirectional DC-DC converter, that couples the supercapacitor to the DC bus (Figure2) [1, 8].

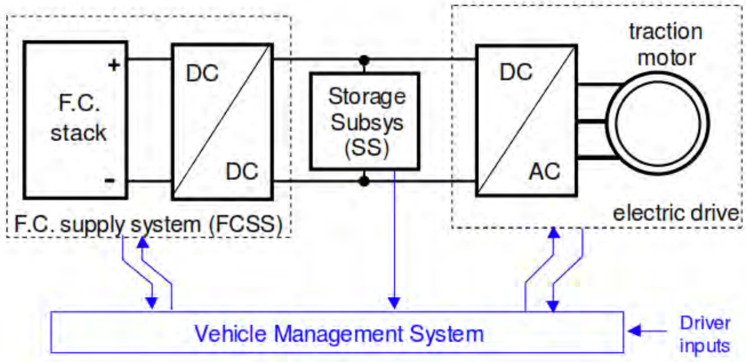

Fig. 2 FCEV with supercapacitor as storage subsystem[8]

3 Additional energy in EV

3.1 Solar cells

On the small surface area of the car, not enough solar energy can be produced for its movement. So solar panels currently do not great impact on the efficiency of electric cars. The constant development of technology will provide better conditions in the years that they follow.

Today's electric vehicles could, under ideal conditions, generate solar energy to extend their range by about 15%. The surface of the nose of the vehicle, through the hood, all the way to the roof can be used for solar cells as shown in Figure 3. Also, the development of technology will no doubt make progress in increasing the efficiency of solar energy [9].

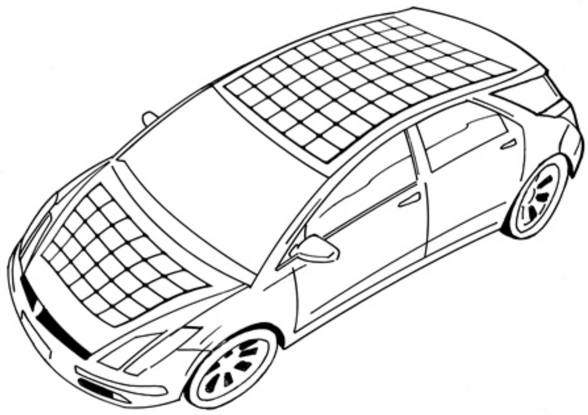

Fig. 3 EV with solar cells

3.2 Energy recovery systems

3.2.1 Kinetic energy recovery system

A kinetic energy recovery system (KERS) is an automotive system for recovering a moving vehicle's kinetic energy under braking. The recovered energy is stored in a reservoir (flywheel or a battery or/and supercapacitor) for later use under acceleration. The device recovers the kinetic energy that is present in the waste heat created by the car's braking process. It stores that energy and converts it into power that can be called upon to boost acceleration, in [1, 10].KERS technology works like a turbo charger that provides additional power and acceleration by stiffening the tail of the ski in out-turns. The effect: a boost, catapulting the rider into the next turn, just like when Formula 1 pilots push a button for that extra notch of speed. KERS technology is an electronic, fully automatic and integrated system. Electrical energy is immediately released when additional energy is requested. Timing and release are automatically controlled and coordinated [1, 11].

3.2.2 Waste heat energy recovery

In recent years, there has been active research on exhaust gas waste heat energy recovery for automobiles. Meanwhile, the use of solar energy is also proposed to promote on-board renewable energy and hence to improve their fuel economy. New research in thermo electric photovoltaic hybrid energy systems are proposed and implemented for automobiles. The key is to newly develop the power conditioning circuit using maximum power point tracking so that the output power of the proposed hybrid energy system can be maximized. This experimental concept can be easily implemented in electric vehicles (Figure 4) [1, 12].

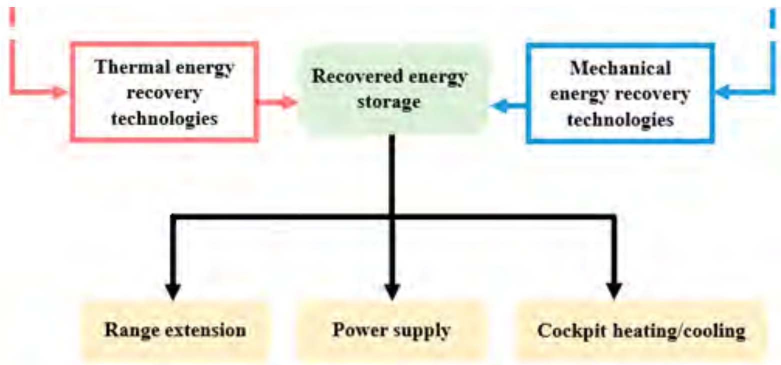

Fig. 4 Energy recovery [12]

3.3 Airflow

The vehicle body can be designed to reduce downforce and otherwise unfavorable air flow, but there is always a large loss of energy, especially at high speeds. Part of the airflow energy can be returned to the system. Some of the possibilities are presented here. During the forward motion of an electric vehicle, air is captured at the front of the vehicle using the channels to one or more turbines with generators for the production of electricity, i.e. it is used to charge the batteries that power the vehicle [1, 13], Figure 5.

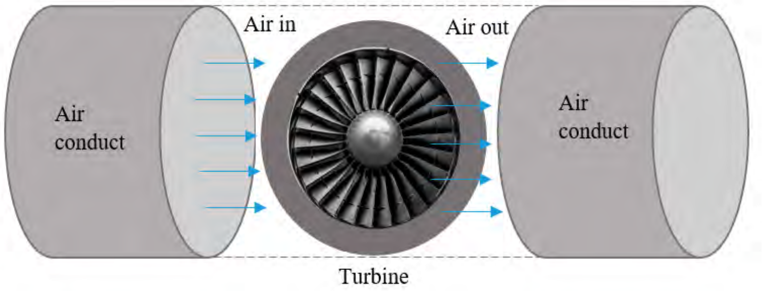

Fig. 5 Airflow energy use [13]

4 Driving optimization

4.1 Comfort, information and safety

Today, a computer is an indispensable part of every vehicle. It supervises and controls practically all the functions of the vehicle, but a lot of additional information is processed and displayed, which significantly contributes to comfort and safety. In EV, this trend is especially used, since the vehicle is equipped with sensors that provide input data and further process in the computer. The obtained results act on the actuators, or the state is shown on the display and the decision is left to man [1].

4.2 Route optimization

Route optimization (RO) is an important feature of the EV which is responsible for finding optimized paths between any source and destination nodes in the road network. Recent researches perform the RO for EV using the Multi Constrained Optimal Path (MCOP) problem. The proposed MCOP problem aims to minimize the length of the path and meets constraints on total travelling time, total time delay due to signals, total recharging time, and total recharging cost. The proposed algorithms need to have innovative methods for finding the velocity of the particles and updating their positions with accurate database of the requested roads [1].

Relevant research on the application of trip distance distributions data specifically to electric vehicles, and in particular battery charging behavior, can be broadly grouped into two categories, neither of which typically includes quantification of resulting GHG emissions. The first category aims to optimize the technological capability, the charging time or the location of the charging stations, with the aim of improving the penetration of electric vehicles. Multi-day trip data was used to maximize mileage and minimize the number of trip interruptions due to charging. Using GPS trajectory data collected from the taxi fleet, the optimization model was developed and found that charger utilization increased and that the number of chargers at each charging point could be reduced by providing a waiting area [14].

5 Conclusion

The paper provides an overview of the situation and presents key points and recommendations for improving the energy efficiency of electric vehicles. The importance of research and development was emphasized in order to achieve the optimal balance between performance, comfort and energy efficiency of electric vehicles. Based on that, future research in this area that will contribute to the global effort for sustainable mobility is indicated.

6 Acknowledgments

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