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Feasibility of Solar Electric Vehicle in Market and It's Challenges

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Abstract
Has been observed that all the global organisations are focusing on sustainable technology that can counter the adverse effects of the products creating issues like greenhouse effect global warming air quality etc. the major contributors in harming the environment are industries and automobile and that has led to global Swift towards sustainable transportation solution. Electric vehicles has emerged as an alternative tool powered vehicle. However the electricity being generated for this automobile is being generated through fossil fuel in the major part of the world. And this global energy scenario shows that only switching to the electric vehicles limits the effect on environment that is being predicted. This paper focuses on implementing solar energy as the primary energy sour for charging electric vehicle batteries and running electric vehicles. Through simulation based analysis comparative studies it the study demonstrate and analyse the major parameters affecting the Solar vehicle technology. This paper also demonstrate through simulation that how this challenges can be solved through a powerful management system. The result shows that overall cost of the system is higher the complexity of the management system is high, in Delhi long term the system shows benefits in greenhouse gas emissions battery health energy saving and overall system efficiency. And this approach very take that the Solar integration in electric vehicle is available option for future electric vehicle development.
EV

Keywords: Solar Electric Vehicle, Power Management System, Dedicated BMS Application, Power Flow Control, Solar Intigrated Electric vehicle.

1. Introduction

Electric vehicles (EVs) are considered to be the most promising alternative to the conventional fuel-based automobile. [1], [2], [3], [4] It has been observed that the automobile sector's contribution to the total global CO2 emissions is 15-25% depending upon the region[5], [6], [7], [8], [9], [10]. Also, it has been observed that globally about 80% Electrical energy generation is done using conventional fuel.[11], [12], [13], [14] Thus including a non-conventional energy source for energy generation contributes to the overall energy efficiency of electric vehicles and solar technology seems to be the most suitable technology to be included in electric vehicles. Nonetheless, the incorporation of solar energy into electric vehicles comes with whole new sets of challenges such as battery health degradation, inconsistent power generation of solar modules, capacity and efficiency of solar modules, constraints of surface area for solar modules. This study presents a power management system to understand the impact of solar integration on battery health, and vehicle performance through a comparative analysis of three different systems, for which a simulation is done in MATLAB Simulink.

Electric Vehicles and Renewable Energy Integration

Worldwide so many initiatives are being taken to reduce carbon emission and among them, Electric vehicles (EVs) are gaining significance. Many governments, industries and individuals are adopting electric vehicle technologies.[15], [16], [17], [18] The use of renewable energy sources is promoted globally. Considering Electric Vehicles, Solar energy is a compelling option due to its sustainability, service life and decentralized nature.[19] A secondary energy source poses a number of challenges whether it's used on board or it is being used as solar-powered charging stations. Although researches has shown that solar integration is improving electric vehicle range but the end effects on the life of the battery and vehicle efficiency are still inadequately examined.

Solar Energy as a Power Source for EVs

Solar energy can be utilised for Electric vehicles mainly in two ways: onboard solar integration or by using a stationary setup for battery charging.[20] In both of these approaches, the main motive is to reduce the dependency on grid electricity. Power generation from solar panels is constrained by the area availability of solar, the efficiency of solar cells and the availability of solar radiation. Also, the storage of energy in chemical

batteries increases the issues related to the degradation of batteries due to irregular power input, power input and output switched after a very short time duration.[18] Using Maximum power point tracking helps in enhancing solar energy utilisation but the frequent changes in input to output power from battery affects the battery performance.[21], [22]
Role of Battery Management Systems (BMS) in Solar Integration
Battery Management Systems (BMS) are required to ensure the performance of the EV batteries.[23] These BMS manage the current flow through it to ensure the battery [24], [25]longevity, temperature control and voltage balancing.[26] While integrating solar into the system, these BMS need to perform some additional functionality like charging and discharging of batteries with respect to variable input from solar modules, and variable output to the motor. Without such functionality, inconsistency in input and output leads to rapid battery degradation. The proposed system with the said functionality ensures that solar energy is utilized at its full potential and becomes a supportive secondary energy source.

Simulation Studies on Solar-Integrated EVs
Previous studies on solar-integrated EVs have focused primarily on the potential for solar energy to extend vehicle range. Few studies have explored the impact of solar integration on battery health. Particularly over the long term[27]. This simulation includes three system configurations, and the results from these simulations are compared to understand the effect of proposed system.

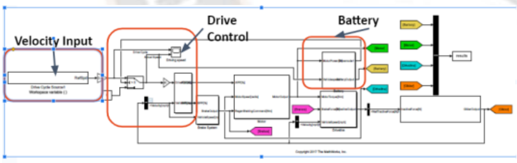

Figure 1 Simulation Model

Methodology
The methodology for the simulation and modelling majorly focuses on the challenges to be face d by solar electric vehicles. The main challenges can be listed as powerful management, thermal management, internal stress generations in battery, life expectancy of the battery, unpredictable power flow.

It is observed that in conventional electric vehicles motor draw power from the battery through a motor controller and regenerative breaking capable microcontroller also allows limited charging of the battery through the power being generated in motors while breaking. Now the integration of solar create triangulation of current flow. It has been observed that current flow from solar can either go to the motors directly or it can go to the more batteries for charging similarly the current flow from the battery can flow towards motor and it can also receive current from solar as well as through regenerative breaking, while motors can either receive current or supply current in case of regenerative breaking.
It has been also observed that current flow from the motor and to the motor is managed free sizely by motor controller on the other hand Solar can only supply more current it cannot take current and no complex power management is required but in case of batteries the batteries can take current from solar and it can supply current to the motor at the same time and if this current flow management is not done it causes chemical damage to the cell which eventually leads to degraded battery life increasing temperature of the battery swelling of the batteries.

It has been considered through this paper that major concern of battery life with solar integration is power flow management and the study is done based on the parameters affecting the power flow management.
During study of the power flow management in Solar integrated electric vehicles it it is seen that the current flow and battery life are in proportion also the temperature of the battery is inversely proportional where the relaxation time is in proportion with the battery life. Power flow management system simulated is design to obstoptimise the relaxation time and power flow directionality based on temperature of the battery and load requirement of the motor.

Simulated model also consider the solar power availability and power fluctuation due to solar.

System Design and Setup
For the comparison Three system configurations were simulated: an existing battery system without solar modules, an existing system with solar modules but no advanced power management, and a proposed system with a dedicated battery management system for directional currents. The methodology involves detailed simulations using MATLAB Simulink. The following sections describe the proposed system for solar integration into electric vehicles.

Data Collection and Performance Metrics
To evaluate the impact of solar integration on electric vehicles, the following data points were collected during the simulations:

Carbon Emissions
- CO2 Emissions (tons/year): Karbonn emissions were calculated based on the requirement of standard coal for generation of the power being consumed by the electric vehicle in a year. .

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Energy Efficiency

- Vehicle Energy Efficiency (%): the overall energy efficiency of the vehicle is simulated that allows comparison of how Solar sour contributes to the propulsion of the electric vehicle and helps in improving battery life.

Simulation Results

System comparison and discussion

Solar energy integration into electric vehicles brings significant environmental benefits, particularly by reducing the reliance on electricity generated from fossil fuels. This section presents the key findings on how solar-powered EVs contribute to reducing carbon emissions and enhancing energy efficiency.

Reduction in Carbon Emissions

One of the primary environmental benefits of solar integration in EVs is the reduction in carbon emissions. According to a simulation conducted on different systems (traditional EVs, solar-integrated EVs, and hybrid systems), vehicles with solar power integration showed up to a 30% decrease in overall emissions. This reduction is primarily due to decreased dependence on grid electricity, which is often generated from coal or natural gas. By shifting some of the energy demand to solar power, EVs contribute to lowering CO2 emissions in regions where the grid is less green.

Figure 1 illustrates the comparative CO2 emissions for conventional EVs using grid electricity, solar-powered EVs, and hybrid models over a 1-year period. The results show a significant drop in emissions for solar-integrated vehicles.

EV Type	CO2 Emissions (tons/year)
Conventional EV (Grid)	2.5
Hybrid EV (Grid + Solar)	1.8
Solar-Integrated EV	1.2

Improved Energy Efficiency

Incorporating solar energy into electric vehicles enhances energy efficiency, primarily by providing an alternative source of power during the daytime, when solar panels can convert sunlight into usable energy for propulsion or battery charging. Simulation results indicate that the energy efficiency of solar-integrated EVs increases by approximately 15% compared to traditional EVs relying solely on grid electricity. This increase in efficiency is due to the reduced energy loss associated with the conversion and storage of solar energy compared to the typical energy transfer processes in grid-based EVs.

Parameter	Conventional EV	Solar-Integrated EV
Energy Efficiency (%)	75%	90
Solar Contribution (kWh/day)	0	4
Reduction in Grid Use (%)	0	30

The use of a Maximum Power Point Tracking (MPPT) system optimizes the energy output from the solar modules, ensuring that solar panels operate at their most efficient point throughout the day. This approach maximizes the amount of solar energy utilized by the vehicle, reducing the load on the battery and enhancing its longevity.

Battery Life and Vehicle Performance

A major challenge in integrating solar power into electric vehicles is the impact on battery life. Irregular power input from solar panels, especially in variable weather conditions, can lead to fluctuations in battery charging cycles. Without proper management, this could degrade the battery's health and reduce its lifespan.

However, the integration of advanced Battery Management Systems (BMS), designed to handle variable solar input, mitigates these risks. As shown in the table below, the implementation of an enhanced BMS system significantly improves battery health and performance. With the enhanced BMS system, the lifespan of batteries in solar-integrated vehicles is extended by approximately 20%, as it prevents overcharging and overheating, which are common issues in conventional systems.

Parameter	Conventional EV	Solar-Integrated EV
Battery Degradation Rate (%)	10%	8
Vehicle Range (km/charge)	300	320
Expected Battery Life (years)	8	10

Additionally, the improved power management ensures that the vehicle can maintain a stable range even during low-sunlight conditions, further enhancing the performance reliability of solar-powered EVs.

Challenges and Limitations

While the proposed system clearly outperforms the other configurations, there are several challenges and limitations that must be addressed:

Solar Availability

One of the main limitations of solar-powered EVs is the variability of solar availability. As demonstrated by the differences between actual and simulated data, solar energy is not always consistently available due to factors such as weather, geographic location, and vehicle orientation. This can limit the benefits of solar integration in certain environments.

Real-World Battery Degradation

While the proposed system shows promising results in both simulations and actual testing, real-world factors such as mid-life degradation and thermal stress still pose challenges. The faster degradation observed after 40% SOH in actual testing highlights the need for more robust solutions to manage battery health in the long term.

Scalability and Implementation

The proposed system's advanced BMS is highly effective in managing multiple battery modules and solar integration, but its complexity may present challenges for large-scale implementation. Further research is needed to simplify the system and reduce costs to make it more accessible for commercial EVs.

Conclusion

Solar energy integration into electric vehicles offers substantial environmental benefits, primarily by reducing carbon emissions and enhancing energy efficiency. The use of solar energy reduces the dependency on grid electricity and lowers the overall carbon footprint of EVs. However, the integration of solar panels poses challenges, particularly related to battery health and the limited power generation capacity of current solar technologies. Advanced Battery Management Systems can mitigate some of these issues, extending battery life and improving vehicle performance. While the initial costs of solar integration are high, the long-term environmental and financial advantages make it a promising solution for the future of sustainable transportation. Further research and technological advancements will be crucial in overcoming the existing limitations of solar-powered EVs.

References

[1] Y. Bicer and I. Dincer, "Life cycle environmental impact assessments and comparisons of alternative fuels for clean vehicles," *Resour Conserv Recycl*, vol. 132, pp. 141–157, May 2018, doi: 10.1016/j.resconrec.2018.01.036.

[2] J. A. Sanguesa, V. Torres-Sanz, P. Garrido, F. J. Martinez, and J. M. Marquez-Barja, "A review on electric vehicles: Technologies and challenges," Mar. 01, 2021, *MDPI*. doi: 10.3390/smartcities4010022.

[3] T. Selmi, A. Khadhraoui, and A. Cherif, "Fuel cell–based electric vehicles technologies and challenges," Nov. 01, 2022, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1007/s11356-022-23171-w.

[4] M. Kebriaei, A. H. Niasar, and B. Asaei, "Hybrid electric vehicles: An overview," in *2015 International Conference on Connected Vehicles and Expo, ICCVE 2015 - Proceedings*, Institute of Electrical and Electronics Engineers Inc., Apr. 2016, pp. 299–305. doi: 10.1109/ICCVE.2015.84.

[5] S. Solaymani, "CO2 emissions patterns in 7 top carbon emitter economies: The case of transport sector," *Energy*, vol. 168, pp. 989–1001, Feb. 2019, doi: 10.1016/j.energy.2018.11.145.

[6] J. Hofmann, D. Guan, K. Chalvatzis, and H. Huo, "Assessment of electrical vehicles as a successful driver for reducing CO2 emissions in China," *Appl Energy*, vol. 184, pp. 995–1003, Dec. 2016, doi: 10.1016/j.apenergy.2016.06.042.

[7] A. Faiz, "AUTOMOTIVE EMISSIONS IN DEVELOPING COUNTRIES-RELATIVE IMPLICATIONS FOR GLOBAL WARMING, ACIDIFICATION AND URBAN AIR QUALITY," 1993.

[8] G. R. Timilsina and A. Shrestha, "Transport sector CO2 emissions growth in Asia: Underlying factors and policy options," *Energy Policy*, vol. 37, no. 11, pp. 4523–4539, Nov. 2009, doi: 10.1016/j.enpol.2009.06.009.

[9] H. Wang, X. Ou, and X. Zhang, "Mode, technology, energy consumption, and resulting CO2 emissions in China's transport sector up to 2050," *Energy Policy*, vol. 109, pp. 719–733, 2017, doi: 10.1016/j.enpol.2017.07.010.

[10] H. Shiraki, K. Matsumoto, Y. Shigetomi, T. Ehara, Y. Ochi, and Y. Ogawa, "Factors affecting CO2 emissions from private automobiles in Japan: The impact of vehicle occupancy," *Appl Energy*, vol. 259, Feb. 2020, doi: 10.1016/j.apenergy.2019.114196.

[11] N. Abas, A. Kalair, and N. Khan, "Review of fossil fuels and future energy technologies," *Futures*, vol. 69, pp. 31–49, May 2015, doi: 10.1016/j.futures.2015.03.003.

[12] M. Hasanuzzaman, U. S. Zubir, N. I. Ilham, and H. Seng Che, "Global electricity demand, generation, grid system, and renewable energy polices: a review," May 01, 2017, *John Wiley and Sons Ltd*. doi: 10.1002/wene.222.

[13] R. G. Newell, D. Raimi, and G. Aldana, "Global Energy Outlook 2019: The Next Generation of Energy," 2019. [Online]. Available: www.rff.org/geo.

[14] M. K. Mubbert, "SCIENCE Energy from Fossil Fuels," 1949.

[15] G. Saldaña, J. I. S. Martín, I. Zamora, F. J. Asensio, and O. Oñederra, "Analysis of the current electric battery models for electric vehicle simulation," *Energies (Basel)*, vol. 12, no. 14, 2019, doi: 10.3390/en12142750.

[16] J. P. F. Trovão and P. J. G. Pereirinha, "Control scheme for hybridised electric vehicles with an online power follower management strategy," *IET Electrical Systems in Transportation*, vol. 5, no. 1, pp. 12–23, Mar. 2015, doi: 10.1049/iet-est.2013.0038.

[17] F. F. Assadian, "Advanced Control and Estimation Concepts and New Hardware Topologies for Future Mobility," Feb. 01, 2022, *MDPI*. doi: 10.3390/en15041568.

[18] R. Capata, "Urban and extra-urban hybrid vehicles: A technological review," Nov. 01, 2018, *MDPI AG*. doi: 10.3390/en11112924.

[19] H. Wang, X. Yang, X. Xu, and L. Fei, "Exploring opportunities and challenges of solar pv power under carbon peak scenario in china: A pest analysis," *Energies (Basel)*, vol. 14, no. 11, Jun. 2021, doi: 10.3390/en14113061.

[20] O. Kanz, A. Reinders, J. May, and K. Ding, "Environmental impacts of integrated photovoltaic modules in light utility electric vehicles," *Energies (Basel)*, vol. 13, no. 19, Oct. 2020, doi: 10.3390/en13195120.

[21] M. M. Titirici, "Sustainable Batteries—Quo Vadis?," *Adv Energy Mater*, vol. 11, no. 10, Mar. 2021, doi: 10.1002/aenm.202003700.

[22] R. He *et al.*, "Towards interactional management for power batteries of electric vehicles," Jan. 11, 2023, *Royal Society of Chemistry*. doi: 10.1039/d2ra06004c.

[23] R. He *et al.*, "Towards interactional management for power batteries of electric vehicles," Jan. 11, 2023, *Royal Society of Chemistry*. doi: 10.1039/d2ra06004c.

[24] L. Ma, C. Zhang, J. Wang, K. Wang, and J. Chen, "Study on capacity estimation methods of second-life application batteries," *World Electric Vehicle Journal*, vol. 12, no. 4, Dec. 2021, doi: 10.3390/wevj12040163.

[25] Y. Iwafune and K. Ogimoto, "Economic impacts of the demand response of electric vehicles considering battery degradation," *Energies (Basel)*, vol. 13, no. 21, Nov. 2020, doi: 10.3390/en13215771.

[26] J. S. T. Souza and N. C. A. de Sousa, "Temperature influence on mobility and charge density model of photovoltaic cells," *Revista Brasileira de Ensino de Física*, vol. 41, no. 3, 2019, doi: 10.1590/1806-9126-rbef-2018-0272.

[27] F. F. Assadian, "Advanced Control and Estimation Concepts and New Hardware Topologies for Future Mobility," Feb. 01, 2022, *MDPI*. doi: 10.3390/en15041568.

[28] Q. Yang *et al.*, "An improved vehicle to the grid method with battery longevity management in a microgrid application," *Energy*, vol. 198, May 2020, doi: 10.1016/j.energy.2020.117374.