Review of a Solar-Assisted Electric Vehicle for Transport and Smart Cafe Use

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ABSTRACT - This paper describes the design and development of a solar-assisted EV focusing on integrating sustainable transport with mobile smart café functionality. The new concept integrates PV, an intelligent battery manager, and module cafe format to create a carbon-neutral dual-use vehicle with unlimited entrepreneurship potential. Demonstrating the Technical Design, Energy Management and Socio-Economic impact for such vehicles include results describing the technical design of an electrical vehicle along with energy management strategies to deploy them in urban as well as semi-urban areas.

Key Words: Solar-Assisted EV, Photovoltaic System ,Battery Storage, BLDC Motor, Inverter, Energy Management, Smart Café, IoT Monitoring, Sustainable Transport, Renewable Energy

1.INTRODUCTION

Population growth and urbanization have drastically elevated energy demand and environmental pollution. Conventional fossil-fuel powered vehicles also contribute to greenhouse gas emissions and air pollution. The transportation sector is responsible for almost a quarter of global CO_2 emissions, according to the International Energy Agency [1], [2]. Urging need of course clean and sustainable mobility solutions

Electric Vehicles (EVs) are becoming a viable substitute for internal combustion engine vehicles because of their high efficiency, low maintenance cost and no tailpipe emissions [3]. But EVs depend heavily on grid electricity, which in many areas may still be fossil fuel based. Integration of renewable energy sources like solar power into EV systems is vital for enhancing sustainability further.[4]

Solar energy is one of the most abundant resources that are renewable in nature, especially for countries like India. The Ministry of New and Renewable Energy has been advocating for solar energy deployment through various national solar missions and subsidy programs [5], [6]. In this context, Solar-Assisted Electric Vehicles (SAEVs) use photovoltaic (PV) panels fixed onto the vehicle body or external solar charging station do charge their batteries. Optimize energy use to reduce reliance on grid electricity and improve vehicle range [7].

However, recent developments of technology including lithium-ion batteries [7], Maximum Power Point Tracking (MPPT) controllers, and energy management systems make them more conducive for solar integration than before [8], [9]. Organisations like the International Renewable Energy Agency stress the need of utilizing renewable energy in conjunction with electric mobility for reaching carbon neutrality objectives [10].

Additionally, a Smart Café system will incorporate a solar-assisted electric vehicle as a mobile multi-purpose (MP) unit that allows business owners to develop their own entrepreneurial endeavors in an environmentally friendly manner. Using solar energy from the onboard batteries [11], [12], the Smart Café vehicle will have induction cooking devices, coffee machines, lights, refrigeration systems, and will accept payments through digital methods from customers. Innovations such as these are in line with the objectives of the Sustainable Urban Development Initiative (SUDI) established by the Government of India’s policy-making arm, NITI Aayog [13].

Thus, the objective of this research proposal is to produce a solar-assisted electric vehicle that has two functional purposes—(1) to provide a means of transportation, and (2) to function as an MP café—and to optimize the design of this vehicle based upon the harvested solar energy, the onboard battery storage, and the power management systems (i.e., the electrical circuits connected to the onboard components) [14],[15].

2.LITERATURE REVIEW

- Solar electric vehicles: Previous research has shown it's possible to combine photovoltaic (PV) panels with electric vehicles (EVs) to increase their total range.

- Mobile services: The popularity of food trucks/mobile cafes has grown; however they were generally reliant on use of diesel generators as a source of power.

- Smart systems: IoT-enabled appliances and digital payment systems increase the overall customer experience and operational efficiency. This study includes the combination of the two above mentioned classes to create a solar mobile unit with a smart cafe infrastructure.

3. SYSTEM DESIGN

3.1 Vehicle Architecture

- Lightweight vehicle chassis (cafe module is a modular design that attaches to EV)

- Flexible solar panels (mounted on the roof and side of the vehicle) with capacity of 1.5 - 2.5kW.

- Lithium-ion/Lithium Iron Phosphate (LFP) battery pack with capacity of 40 - 60kWh

- Dual inverter system (one for the traction motor and one for the cafe appliances)

3.2 Energy Management

- Maximum Power Point Tracking (MPPT) (solar)

- Smart Battery Management System (BMS) with load priority

- Hybrid charging systems (solar + Utility grid)

3.3 Smart Cafe Module

- Energy efficient appliances (ie coffee machines, grinders, refrigeration units)

- IoT enabled monitoring and control systems

3.4 Control/communication systems:

- Integration of IoT; sensors for solar input, battery health, and appliance load.

- User Interface; Dashboards for driver and cafe operator.

- Connectivity; Cloud-based monitoring capabilities and predictive maintenance notifications.

- Safety systems; Overcurrent protection, thermal protection, emergency cutoff.

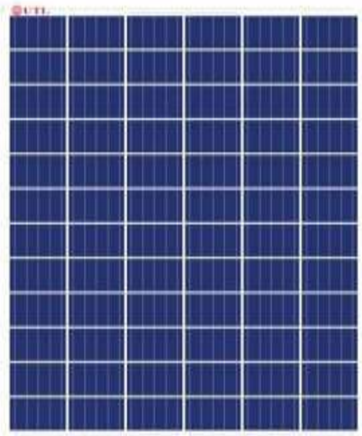

Fig. Solar Panel

Fig. Refrigerator

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Fig. Coffee machine

Fig. Grinder

4. PERFORMANCE ANALYSIS

- Energy Balance Calculations: Determine the amount of Solar Input, the size of the cafe load, and whether or not you will have enough power to drive.
- Simulation Results: MATLAB/Simulink or ANSYS modelling of energy flows.
- Prototype Testing: Extending range due to having solar panels; maintaining cafe operation times.
- Comparison with Conventional Vehicles and with Diesel-powered Mobile Cafes.

5. DESIGN PROCESSES

1.Estimate Your Total Loads

When estimating your total load you will need to consider:

- Traction Loads (Vehicle Movement)
- Auxiliary Loads (Smart Cafe Appliances)

Appliance	**Power (W)**	**Usage (hrs/day)**	**Energy (Wh/day)**
Coffee Machine	800 W	3 hrs	2400 Wh
Grinder	300 W	2 hrs	600 Wh
Refrigerator	150 W	8 hrs	1200 Wh
Lighting + IoT	100 W	6 hrs	600 Wh
Total Café Load	—	—	**4800**

Vehicle Load

- The Electric Vehicle (EV) operating at an energy use rate of 150 Wh/km requires 15,000 Wh of energy per day for the 100 km/day driving distance. The total daily energy use (both EV and Cafe) is as follows:
- 15,000 Wh (EV) + 4,800 Wh (Cafe) = 19,800 Wh/day (~20 kWh/day).

2.Battery selection

- requires a minimum of 20 kWh battery capacity with a 20% margin for inefficiencies: 20 kWh x 1.2 = 24 kWh.

Battery Chemistry

- lithium iron phosphate (LiFePO4) batteries are preferred because of their relatively high level of electrical safety and useful cycle life, and have a nominal voltage of 48V (a common voltage for EV & auxiliary systems).

To calculate the battery capacity in Ah: Battery Ah = Energy (Wh)/Voltage (V)

Therefore, Battery Ah = 24,000Wh/48V = 500Ah.

In summary, the battery pack will have a nominal voltage of 48V and 500Ah **(approximately 24kWh).**

3) Battery architecture for charging:

- The battery pack will have a series-parallel configuration of batteries (i.e. 16 batteries in series, each one with an nominal voltage of 3.2V (for a total of 51.2V)),
- parallel strings sized to meet the 500Ah capacity required. Displayed in Figure 2 is an example of the configuration described above.

4) The current requirement:

- For the various loads associated with the EV is calculated as follows: The motor requires 10 kW (peak) at 48V: I = P/V = 10,000W/48V ~ 208A.
- The café appliances require a maximum of 2kW at 48V: I = 2,000W/48V ~42A.
- The design current capacity is therefore designed for the peak of simultaneously operating both loads (250A).

5) The solar panel sizing:

- calculation is based on the energy demand of 20 kWh daily; assuming there are five hours of peak sunlight each day in India, the required solar array size can be calculated:
- Solar Panel Power = Daily Energy(i.e. 20,000,000) / Sun Hours = 4,000W (or 4kW).

6) Practical Consideration:

- The total on-board solar capacity of the vehicle will depend on the total amount of area available on the roof to mount the solar panels. Allowing for flexible PV modules having a power output density of 150 W/m², the maximum amount of area that can be provided on the roof of the vehicle for solar modules will be:

Max Roof Area = 1.2 kW

- Thus, the required additional solar panel capacity (beyond 1.2 kW) can be met with either 1.2 kW of portable, foldable solar panels or with a portable charging dock that can be plugged into the grid or a generator. The overall solar panel setup will consist of 1.2 kW of solar capability mounted to the roof of the vehicle and an additional 3 kW of portable solar modules/charging stations.

6. CHARGING ARCHITECTURE

- Simply convert solar energy to battery storage on board.
- Use AC/DC chargers for charging power during cloudy days.
- A two separate systems to charge the bus (one high voltage, one low voltage). Traction high voltage for bus motor and café appliances use low-voltage.
- Governance of energy management prioritizes traction and surplus for café use.

7. SUMMARY WORKING MODEL

- Battery Pack 48 V, 500 Ah (24 kWh $LiFePO_4$).
- Current (A) 250 A Peak.
- Solar Panels 4 kW total (1.2 kW mounted on bus + 3 kW portable).
- Daily range of approximately 100 km + 6 to 8 hours of café operation.
- Charging solar and charging grid hybrid (with MPPT and BMS utility).

8. SOCIO-ECONOMIC IMPACT

- Value of CO2 reduction, benefits to the adoption of renewable energy.
- Creation of new business models for mobile cafés.
- Educating and creating a positive awareness around sustainable practices to the local resource community.

9. FUTURE WORK

Develop a prototype for testing and validating the energy balance and operational performance.

Conduct simulation studies of the solar input, battery discharge cycles, and café load profiles using MATLAB/Simulink-based modeling.

Optimize the design by exploring lighter materials for the chassis and high-efficiency solar panels.

Pilot the MSTB business model to validate customer adoptions by deploying bus prototypes to campus, smart cities, and tourist hubs.

Research the potential for fleet-based deployment and connectivity to the smart grid..

10. CONCLUSION

The concept of establishing a combined and sustainable transport, with potential for entrepreneurial development through creating an innovative transport system for both commercial and recreational use using solar assisted electric vehicles within a smart café context, is demonstrated through this proposal. The system utilizes solar energy for powering both the mobile café and the electric vehicle, and in the process, reduces CO2 emissions, expands the range of the electric vehicle, and thus supports a mobile application platform. The design initiative demonstrates how potential business operations that are environmentally sustainable could be successful in both urban and semi-urban environments.

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