ISSN Number: 2454-2024(Online)
International Journal of Technical Research & Science

SOLAR ASSISTED REFRIGERATING E-RICKSHAW SYSTEM USED FOR STREET VENDORS

Surender Kumar, R.S. Bharj
E-Mail Id: surender10161007@gmail.com, bharjrs@nitj.ac.in
Department of Mechanical Engineering Department, NIT, Jalandhar (PB), India

Abstract- Electric vehicles are widely used in urban cold chain logistic delivery. Temperature-sensitive logistics are more challenging for small order deliveries in terms of cost and time constraints. Sustainable development of cold chain logistics is essential in road transportation. The solar-assisted refrigerating E-rickshaw has been proposed in this study. The performance of this system was analyzed under different operating conditions. The impact of changing the load on maximum vehicle speed and trip distance was investigated. The solar panel produced an average of 3140 Wh of solar energy in one sunny day. The vehicle was reached a maximum speed of 23 km/h while carrying a 200 kg load. The vehicle covered a distance of 60.4 km with the battery bank alone at 200 kg load condition. It was traveling 63.4 km distance with hybrid energy mode. The solar panel extended the cruising range of the vehicle by 3.2 kilometers.

Keywords: E-mobility, energy consumption, performance, economic analysis.

1. INTRODUCTION

India is the world's second-largest producer of horticulture products. About 25% of perishable products are lost due to inadequate storage and cold chain (CC) transportation infrastructure. The per capita availability of fruits and vegetables is 20–30% of the total production. Modern perishable food distribution systems are a major source of environmental pollution in the CC [1].

The temperature-controlled refrigerating chamber fitted on the vehicles is needed in the current cold chain for food, medicine, fresh and perishable products transportation [2]. The CC is responsible for the safe delivery of high-quality foodstuff to consumers. Most of the perishable produce requires a cooling temperature between 0 to -15 °C for safe storage and transportation purposes [3].

The cold chain logistics industry (CCLI) is under pressure to reduce product storage and delivery costs. If the product's delivery time increases due to any reason, the severe loss of foodstuff quality and food safety cannot be guaranteed. Perishable foodstuff transportation has become more expensive with the development of CCLI. The fresh foodstuff deterioration, higher urban area pollution, and continuous growth of fuel cost are still some hidden dangers in the CCLI [4].

With the awareness of people, these are choosing green and healthy foodstuff in the current time era. The fresh food demand is continuously increasing due to the increasing worldwide population. The government of developing countries is highly focusing on carbon emissions reduction in cold chain transportation to prevent a series of environmental threats [5]. Current cold chain vehicles consume 25% more fuel to preserve perishable goods at a suitable temperature.

More than 40% of food items require refrigerated vehicles during foodstuff delivery. Refrigeration is consuming 53% of the total power in different operations. The global cold chain logistics industry (GCCLI) was worth 160,000 million dollars in 2018. This industry is expected to grow to 585,000 million dollars by 2025. The CAGR of GCCLI is projected as 17.9% [6]. The GCCLI market is divided into five major categories: 1) fruits and vegetables, 2) medicines and pharmaceuticals, 3) meat and seafood, 4) milk products, and 5) bakery [7].

The development of carbon-free megacities is one of the prime goals of many governments all over the world. This target can be achieved globally by gradually reducing fossil fuels and promoting solar energy in GCCLI [8-9].

Refrigerated vehicles (RVs) are suitable for a wide range of deliveries from one city to another city. The ICE-based RVs are confronting some restrictions that available in the current market [10]. RVs used in the current market are neither very energy efficient or cost-effective for small-scale intercity goods deliveries. Therefore, the vehicle manufacturing industries are moving toward developing the latest refrigerating electric vehicle using the newest technologies and materials. This research paper focused on the performance analysis of a solar-assisted refrigerating E-rickshaw system.

2. REVIEW ON SOLAR E- RICKSHAW SYSTEM

The fast deterioration of environmental quality as a result of pollution concerns and the depletion of fossil fuels is driving the world to create alternative technologies such as solar hybrid rickshaws for cold chain logistics industry [11-12]. In the developing world, solar hybrid rickshaws have gained significant attention as a green and sustainable transportation alternative to traditional fossil fuel-powered load carrying vehicles. The past studies on solar E-rickshaw system are reviews in table 2.1.

Table- 2.1 Review on Solar E- Rickshaw System

Author & Year	Type of solar panel & motor used	Type of rickshaw & output parameters measured
Gurkaynak et al., 2009 [13]	Poly-crystalline silicon photovoltaic array; BLDC motor.	• Photovoltaic-battery operated electric auto rickshaw; • PV array voltage and power; • Vehicle driving distance range.
	Short description: For the Indian market, a novel solar hybrid electric auto-rickshaw has been proposed. This rickshaw's overall efficiency (70.1%) was higher than conventional auto-rickshaw (19%).	
Mulhall, et al., 2010 [14]	Poly-crystalline silicon photovoltaic array; BLDC motor.	• Solar-assisted electric auto rickshaw; • Current and power consumption of motor; • Distance covered by this rickshaw; • Daytime and evening driving cycle.
	Short description: This paper presents recent design studies, simulations (using ADVISOR software), and experimental validation for a solar-assisted electric auto rickshaw. With an integrated battery system, the Rickshaw's technological development goal was to reduce the total electric power needed for propulsion. This rickshaw was covering 90 km in a hybrid mode of energy.	
Reddy & Sarma, 2012 [15]	Mono-crystalline silicon photovoltaic panel; DC motor.	• Solar-power assisted vehicle prototype; • The power produced by solar panel; • Distance covered by the vehicle.
	Short description: A prototype of the electric vehicle was developed. The performance of the electric vehicle was compared with the conventional car.	
Siddique et al., 2013 [16]	Mono-crystalline silicon type solar module; DC-motor (48 V).	• Solar-power assisted ambulance; • Battery current and voltage; • PV current and voltage; • Energy consumption of the DC motor.
	Short description: The solar-powered rickshaw ambulance was designed for use in rural areas. MATLAB (Simulink) was used to examine the solar panel's performance. The proposed model was compared with other existing modes of transport system in the rural health sector.	
Rhaman & Toshon, 2014 [17]	Four 75W solar panels; BLDC motor.	• Solar-powered and pedal-assisted rickshaw; • Motor speed variation with power consumption; • PV current and voltage.
	Short description: Solar Power Rickshaw was reducing the physical labor of the manually-paddled rickshaw. This rickshaw was running at 25 km per hour that was faster than conventional Rickshaws.	
Sameeullah & Chandel, 2016 [18]	560 W PV system; BLDC motor.	• Solar assisted hybrid electric rickshaw; • Solar irradiance; • The power output of the solar panel; • Financial analysis of this vehicle.
	Short description: The performance of this vehicle was analyzed by using Matlab and software. The solar E-motor rickshaw was consuming 42 Wh/Km of energy and covered 124 kilometers.	
Reddy et al., 2017 [19]	Two mono-crystalline solar panels (470 W); BLDC motor (48 V).	• Solar-powered electric auto-rickshaw (SPEAR); • Solar irradiance; • The power output of the solar panel; • Vehicle speed and battery discharge rate; • Economic analysis of the vehicles.
	Short description: With a battery discharge rate of 296 W at 90 kg load, the vehicle was reached a top speed of 21.69 km/h. With a maximum discharge rate of 540 W at 390 kg load, the vehicle reached a top speed of 12.11 km/h.	
Karim & Shahid, 2018 [20]	Four solar panels; BLDC motor.	• Conventional petrol car converted into the solar-electric hybrid car; • Power consumed by the BLDC motor; • Battery voltage; • Distance covered by the vehicle.
	Short description: This converted car was able to cover 60 km in a single charge. The battery	

	bank was able to store 5760 Wh of energy. Maximum 50% energy can be drain-out from the lead-acid battery, which means DC motor maximum energy was using 2880 Wh. The BLDC motor of this vehicle was consuming 48 Wh/km.	
Waseem et al., 2019 [21]	PV panels used; BLDC motor.	• Solar PV technology is integrated with electric and hybrid vehicles.
	Short description: The Indian transportation sector was demanding green-powered electric vehicles. The use of solar PV technologies in battery, hybrid, and self-driving cars was demonstrated.	
Nambisan et al., 2020 [22]	Two poly-crystalline silicon photovoltaic; BLDC motor.	• Solar assisted battery and super-capacitor-based E-rickshaw; • Motor power requirement; • Economic analysis of the vehicle.
	Short description: The E-rickshaw (solar-assisted battery and super capacitor-based) was modeled and simulated in MATLAB. As compared to lead-acid batteries, the super-capacitor has a lower environmental effect. The cycle life of the super-capacitor (2.7V, 350F) was 500,000 cycles, and the cost was INR 776.03.	
Dhar et al., 2021 [23]	Test without solar panel; BLDC motor.	• E-auto rickshaw; • Cost comparison of various motors; • Cost comparison for EV and gas-powered auto-rickshaws; • Torque-speed characteristics of BLDC motor.
	Short description: Due to the continued growing fuel prices and stricter emission rules in developing countries, the short-range transportation industry is shifting to EVs. BLDC motors were potent and light, delivering constant power over a broad speed spectrum, making them ideal for short-range transportation.	

Some studies have already been done on solar electric rickshaw systems, but very limited work is done on integral system of solar refrigerated E-rickshaw. Previous research had several shortcomings in terms of integral system performance, energy savings, and economic analyses. Therefore, the present work focuses on the performance analysis of a solar-assisted refrigerating E-rickshaw system.

3. TRACTIVE FORCE REQUIRED

Tractive effort ($F_{tractive}$) is required to move this vehicle in the longitudinal direction. Tractive effort acting on this vehicle is shown in figure 3.1. The mathematical expression (Newton Second Laws of motion) between forces and acceleration in the longitudinal direction (X-direction) for the vehicle is shown by equation (1).

$$F_{tractive} = \lambda M \frac{dV_x}{dt} + \sum F_{resistive} \quad (1)$$

$F_{tractive}$ is the total tractive effort acting on the wheel of this vehicle in the x-direction, M is the total mass of this vehicle, dV_X/dt is torque required to move this vehicle, or electric propulsion to overtake the resistive forces. The resistive forces acting on this vehicle in the x-direction are presented in equation (2).

$$\sum F_{resistive} = \underbrace{Mg\sin\alpha}_{grade} + \underbrace{Mg\mu_r\cos\alpha}_{roll} + \frac{1}{2}\underbrace{\rho A_f C_D V_X^2}_{drag} \quad (2)$$

α is the road slope angle, g is the gravitational constant, μ_r is the rolling coefficient of friction (between the contact point of tire and road), ρ is the air density, A_f is the front area of this vehicle, the C_D is the air coefficient of drag and V_X is the longitudinal velocity of this vehicle in the longitudinal direction. The tractive effort required for the vehicle is presented in equation (3).

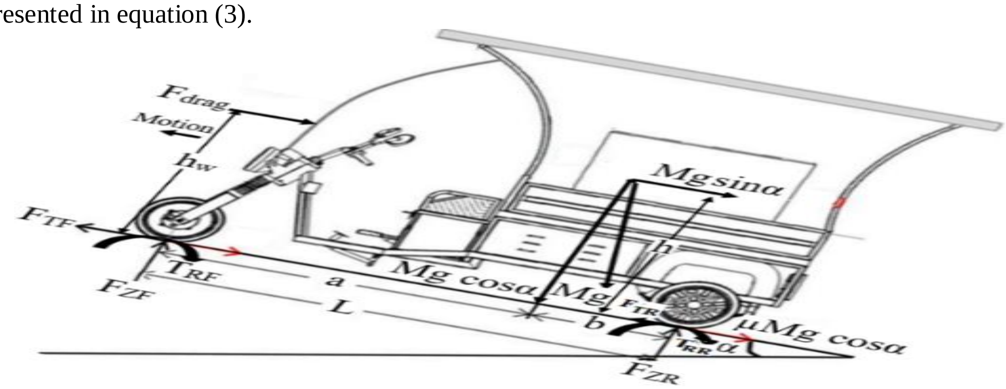


Fig. 3.1 Force acting on the solar refrigerating E-rickshaw

Aerodynamic drag of solar refrigerating E-rickshaw = $\frac{1}{2}\rho C_D A V^2$

Air density @ 27 ^{O}C = ρ =1.2 (kg/m^3)
Vehicle frontal area or projected area = A (Sq. m) = 1249 mm × 1768 mm = 1.249×1.768 = 2.21 m^2
Drag coefficent = C_D = 0.45
1 kmph = (1000/3600) m/sec= 0.278 m/sec
At 5 kmph
Drag (N) = 0.5×1.2×0.45×2.21×(5/3.6)^2 = 1.153 N
At 10 kmph
Drag (N) = 0.5×1.2×0.45×2.21×(10/3.6)^2 = 4.61 N
At 15 kmph
Drag (N) = 0.5×1.2×0.45×2.21×(15/3.6)^2 = 10.375 N
At 20 kmph
Drag (N) = 0.5×1.2×0.45×2.21×(20/3.6)^2 = 18.446 N
At 25 kmph
Drag (N) = 0.5×1.2×0.45×2.21×(25/3.6)^2 = **28.822 N**

Rolling resistance = m×g×μ×cosθ

Permissible load (m) = (m) kg = 460 kg
Weight = mg (newton or kg.m/s^2)
Where g = 9.80665 m/s^2
Rolling coefficent (μ) = 0.015
Rolling resistance at θ (12^o) = m×g×μ×cosθ = 460×9.80665×0.015× cos[12× (π/180)] = **67.665 N**

Uphill resistance or climbing force = mg sinθ

Permissible load (m) = (m) kg = 460 kg
Where g = 9.80665 m/s^2
Climbing force at θ (4^o) = mg sinθ = 460×9.81×sin[4× (π/180)] = 5.496 N
Climbing force at θ (8^o) = mg sinθ = 460×9.81×sin[8× (π/180)] = 10.99 N
Climbing force at θ (12^o) = mg sinθ = 460×9.81×sin[12× (π/180)] = **16.4869 N**

4. EXPERIMENTAL SETUP DESCRIPTION

The experimental set-up consists of a refrigerator (240 L), solar energy production unit (600 W), solar charge controller (PWM), and battery bank (105 Ah). The refrigerator is fitted on the backside of this vehicle. Four PV panels are installed on the vehicle's roof to receive the maximum amount of solar radiation on sunny days. The MPPT solar charge controller is used to regulate the output solar energy fluctuation. The battery bank of this vehicle used four lead-acid batteries which are connected in series. The 48 V battery bank has a capacity of 105 Ah and is used for energy storage as well as powering the compressor and brushless direct-current (BLDC) motor. The battery power is converted into mechanical drive energy using an 850 W BLDC electric motor. The battery protection circuit regulates charge flow and prevents overcharging or deep drain of the battery bank. The vehicle’s refrigerator is driven by a DC compressor (K35 DC ROHS Sol-cool). The refrigerator runs on a 12-12.6 V voltage range. A DC converter (48-12 V) is used to provide enough low voltage for the refrigerator. The low voltage disconnect (LVD) is used to regulate the refrigerator's energy fluctuations. The LVD shuts off the refrigerator's energy supply when the battery voltage reaches a critical level. The battery bank is charged at night using a simple mode power supply charger (SMPS-15 A). The block diagram and complete set-up of solar-assisted refrigerating E-rickshaw are shown in figures 3.1 & 3.2.

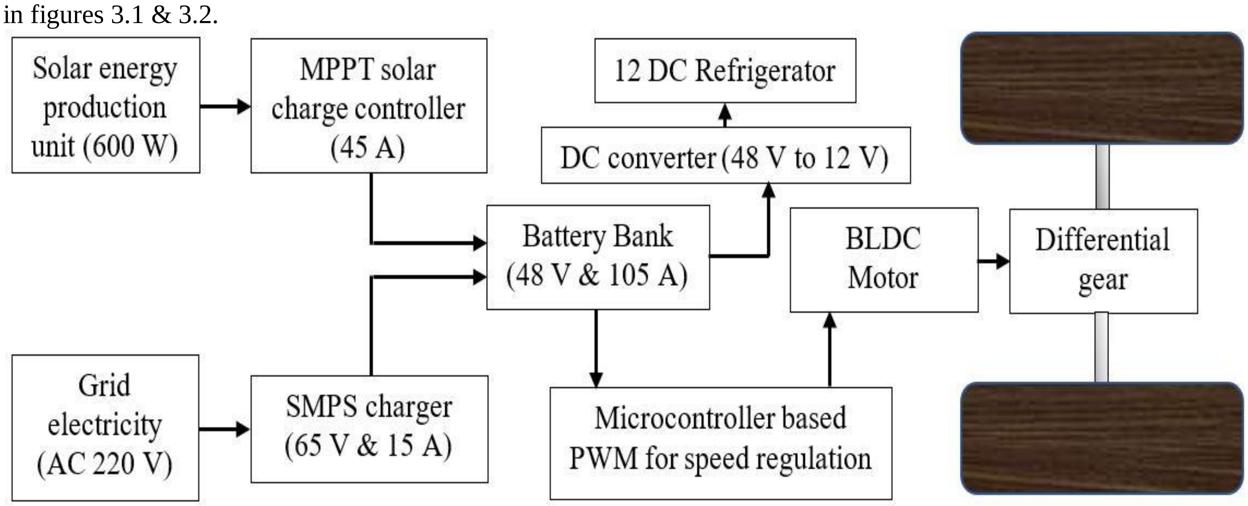


Fig. 4.1 Block diagram for solar-assisted refrigerating E-rikshaw

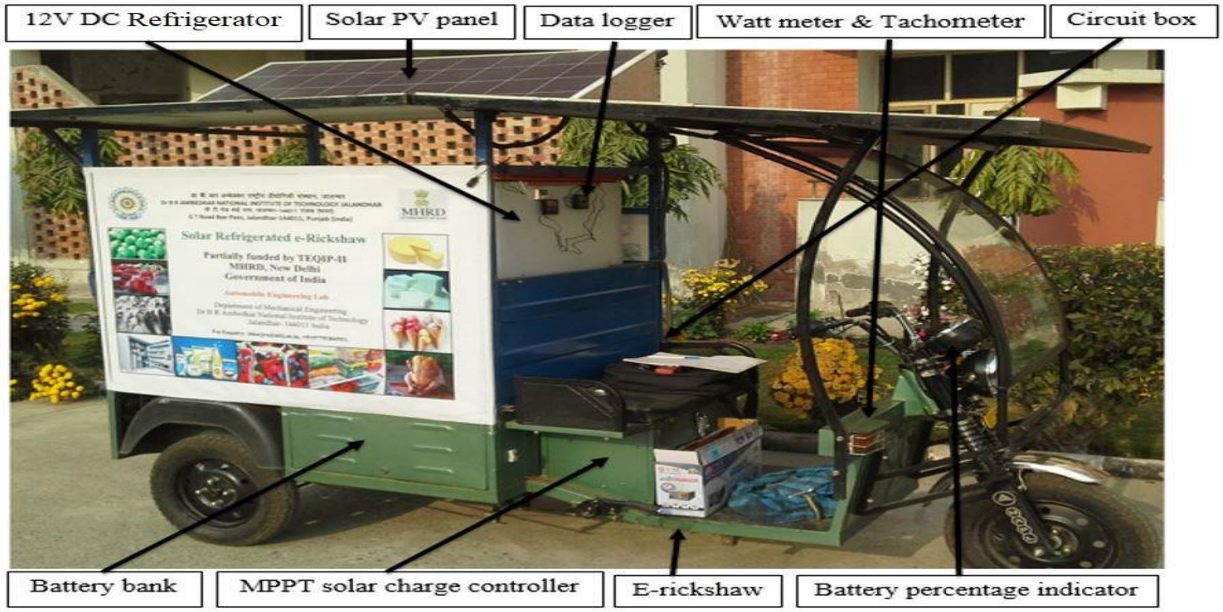


Fig. 4.2 Photographic view of solar-assisted refrigerating E-rikshaw

5. PROCEDURE FOR PERFORMING EXPERIMENTS

All the experiments were carried out at the National Institute of Technology's Department of Mechanical Engineering in Jalandhar, Punjab, India. These experiments were performed between 5th April to 26th May 2019 in the summer season. These experiments are performed with battery bank alone and the hybrid energy mode (B + S). Two digital tachometers (NJK-5002C -Hitsan 4) proximity switch sensors are used to measure motor and vehicle speed. Three digital wattmeters (DC PZEM-051) are used to measure the output current of solar panels, input current of BLDC motor, and DC compressor. A solar pyranometer (Amprobe solar -100) is used to measure the solar radiation falling on the solar panel surface.

The following experimental conditions are maintained across this study:

- The battery bank of the vehicle must be fully charged before starting each experiment.
- The refrigerator chamber door is kept open for 8 hours to maintain thermal equilibrium with ambient air before starting each experiment.
- The door of the refrigerator was kept closed during the experiment time.
- The solar panels are always kept dust-free and have no shade on them throughout the day.
- All these experiments are performed on the same location and same road route in sunny days conditions.

6. RESULTS AND DISCUSSION

The experiments are carried out to analyze the vehicle's performance on typical sunny days. These experiments are divided into three steps. The performance of PV panels is tested in the first step. The refrigerator of this vehicle is tested in the second phase by setting the thermostat position at 7th. The vehicle's performance is tested under various load situations in the third step.

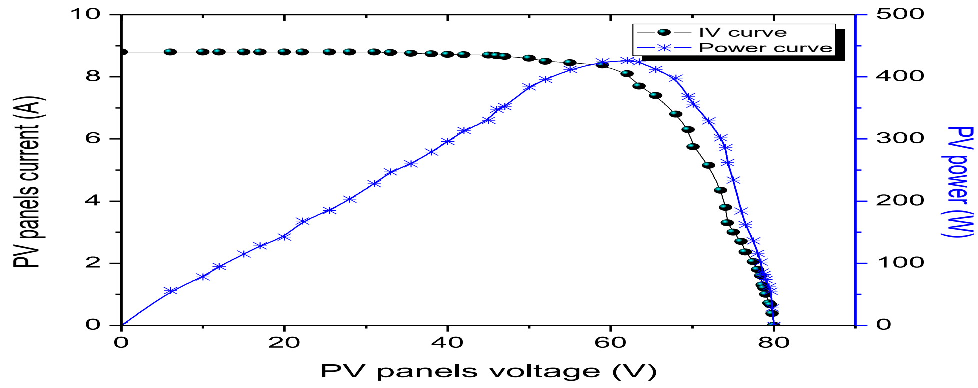


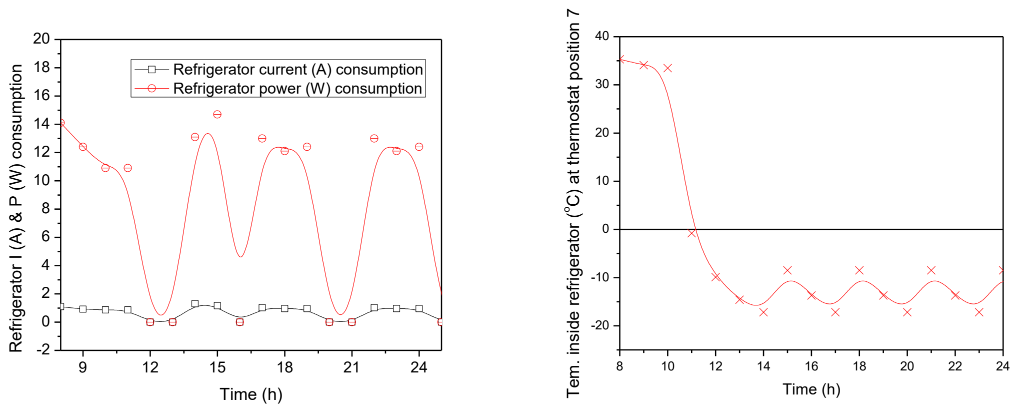
Fig. 6.1 PV panel performance

6.1 Performance test of the PV Panel

The performance of the PV panel on a typical day is shown in figure 6.1. The PV current, voltage, and power output vary in the range of 1.3-8.6 A, 10-62 V, and 55-425 W due to variations in solar irradiation on a typical sunny day. The solar energy generated yields 3.4 kWh of energy on a sunny day.

6.2 Experiment on the DC Refrigerator

This experiment is carried out on a vehicle refrigerator with no load condition. The DC refrigerator's current and power consumption is shown in figure 6.2(a). The results show that the refrigerator consumed a maximum of 1.6 A current and 14.6 W power. The lower average temperature of -14 ^{o}C was maintained inside the refrigerator chamber. The internal temperature variation of the refrigerated chamber is shown in figure 6.2(b).
The voltage variation with the SOC of the vehicle battery bank is shown in figure 6.3. The higher voltage of 51.5 V was recorded for a fully charged battery bank. This vehicle battery bank's cutoff voltage was 46.5 V. The distance traveled by a vehicle when the refrigerator is turned on position is shown in figure 6.4. The vehicle covered 60.2 km with a load of 200 kg in 2.1 hours and consuming 1985 Wh of energy when it runs only on the battery bank. This vehicle traveled 63.4 km in 2.2 hours with a 200 kg load and consuming 3450 Wh of energy when operating in hybrid energy mode. This vehicle's acceleration and pickup time were decreased in hybrid mode.



(a) (b)

Fig. 6.2 Refrigerator (a) current and power consumption (b) chamber inside temperature variation

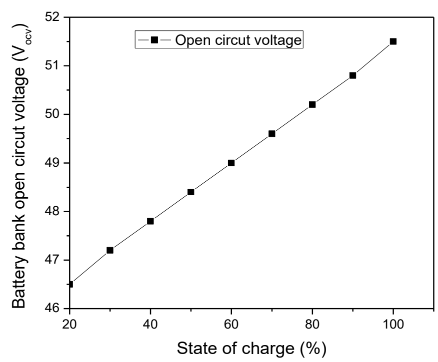


Fig. 6.3 The voltage variation with the state of charge (SOC)

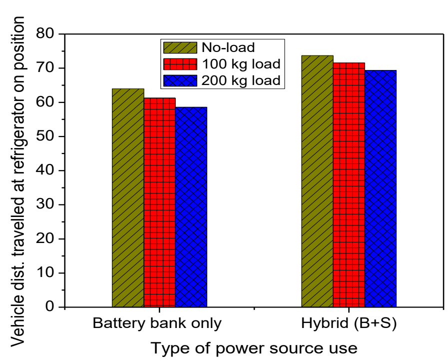


Fig. 6.4 The distance traveled by a vehicle when the refrigerator is turned on position

6.3 Payback Period of Vehicle System with and Without Solar-Assistance

The economic analysis and the payback period are calculated based on the Indian E-vehicle market study.

Case 1: Economic analysis and payback period for solar-assisted refrigerating electric vehicle

Vehicle's total cost = A (cost of vehicle) + B (cost of refrigerating unit) + C (cost of solar unit)
Total cost= A (INR 140000.00) + B (INR 65000.00) + C (INR 26000.00) = INR 231000.00
Solar energy generates by vehicle solar unit = 2-4 kWh (depends on season)
Total solar energy generates by vehicle solar electricity unit per month = Avg. solar unit × 30 = 3.5 × 30 = 105 kWh
Average solar energy available in India 7-8 months per year
Average solar electricity unit generate per year = 105 × 8 = 840 kWh
Single unit cost in Punjab state = 6 INR
Average energy saved per year = 840 × 6 = 5040 INR
Average reservation of this vehicle in a single day = 2- 3 booking
One time booking cost of vehicle = 250-450 INR
Total average cash earn by vehicle in single day = Avg. booking in number × Avg. cost of booking = 2.5 × 350 =875 INR
Cash earn by this vehicle per month = 875 × 30 = 26250.00 INR
Cash earn by this vehicle per year = 26250 × 12 = 315000.00 INR
Total money earns by this vehicle per year = vehicle case earns per year + average energy saved per year = 315000 + 5040 = 320040 INR
Payback period of this vehicle = Total cost of refrigerated vehicle/Total money earns by this vehicle per year
Vehicle's payback period for solar-assisted refrigerating electric vehicle = 231000/320040 = **7.2 months**.

Case 2: Economic analysis and payback period for refrigerating electric vehicle without solar assistance.

Vehicle's total cost = A (cost of vehicle) + B (cost of refrigerating unit)
Total cost= A (INR 140000.00) + B (INR 65000.00) = INR 205000.00
Average reservation of this vehicle in a single day = 2- 3 booking
One time booking cost of vehicle = 250-450 INR
Total average cash earn by vehicle in single day = Avg. booking in number × Avg. cost of booking = 2.5 × 350 =875 INR
Cash earn by this vehicle per month = 875 × 30 = 26250.00 INR
Total cash earn by this vehicle per year = 26250 × 12 = 315000.00 INR
Payback period of this vehicle = Total cost of refrigerated vehicle/Total money earns by this vehicle per year
Vehicle's payback period for refrigerating electric vehicle without solar assistance = 205000/315000 = **6.5 months**.

CONCLUSION

The solar-assisted refrigerating E-rikshaw was constructed for street vendors that are facing the sustainability problem for perishable foodstuff delivery in the CCLI. The vehicle's dimensions are L (2866 mm), W (1249 mm), and H (1768 mm). The performance and energy consumption of this vehicle was studied under different load conditions. This vehicle battery was charged during the day using solar energy and at night with grid electricity.
The following are the key conclusions from the experiments:

- Charging the battery bank with grid electricity required 9.5 kWh of energy and 8-11 hours.
- This vehicle battery bank's energy storage capacity was 5040 Wh.
- The solar energy production unit was produced an average of 3140 Wh of solar energy in one sunny day.
- The battery bank of vehicle was fully charged in 1.6 days using solar energy.
- The vehicle's cruising range was enhanced by 3.2 kilometers after using solar energy.
- The vehicle's refrigerator consumed 98 Wh of energy in one day while maintaining a temperature of -17 ^{o}C.
- The vehicle was travel at 23 km/h speed with a 200 kg load.
- The per-kilometer cost of the vehicle was 1-1.5 INR.
- The vehicle payback period was 7.2 months and 6.5 months, respectively, with and without a solar producing system.
- The vehicle travelled 63.4 kilometers in hybrid energy mode with a load of 200 kg.
- The vehicle's overall performance was improved, while acceleration time was decreased in hybrid energy mode.

This vehicle's operating and maintenance costs were low, making it ideal for street vendors delivering perishable foodstuffs.

REFERENCES

[1] Kondal, K. (2014), "Performance of Horticulture sector in India", International Journal of Scientific

Research, 3 (5) pp. 1-5.
[2] Badia-Melis, R., Ruiz-Garcia, L., Garcia-Hierro, J., & Villalba, J. I. R. (2015), "Refrigerated fruit storage monitoring combining two different wireless sensing technologies: RFID and WSN", Sensors, 15 (3), pp. 4781-4795.
[3] Mercier, S., Villeneuve, S., Mondor, M., & Uysal, I. (2017) , "Time–temperature management along the food cold chain: A review of recent developments", Comprehensive Reviews in Food Science and Food Safety, 16(4), pp. 647-667.
[4] Li, Y., Lim, M. K., & Tseng, M. L. (2019), "A green vehicle routing model based on modified particle swarm optimization for cold chain logistics", Industrial Management & Data Systems.
[5] Prabhu, V., Gupta, S. K., Madhwal, S., & Shridhar, V. (2019), "Exposure to atmospheric particulates and associated respirable deposition dose to street vendors at the residential and commercial sites in Dehradun City", Safety and health at work, 10 (2), pp. 237-244.
[6] Allied Market Research, 2019. Global Cold Chain Logistics Market: Opportunities and Forecast 2019-2026. Accessed on 25th may 2021).
[7] Liu, G., Hu, J., Yang, Y., Xia, S., & Lim, M. K. (2020), "Vehicle routing problem in cold Chain logistics: A joint distribution model with carbon trading mechanisms. Resources", Conservation and Recycling, 156, p. 104715.
[8] Zhang, R., & Hanaoka, T. (2021), "Deployment of electric vehicles in China to meet the carbon neutral target by 2060: Provincial disparities in energy systems, CO_2 emissions, and cost effectiveness", Resources, Conservation and Recycling, 170, p. 105622.
[9] Bach, H., Makitie, T., Hansen, T., & Steen, M. (2021), "Blending new and old in sustainability transitions: Technological alignment between fossil fuels and biofuels in Norwegian coastal shipping", Energy Research & Social Science, 74, p. 101957.
[10] Kumar, S & Bharj, R. (2021), "Experimental analysis of solar assisted refrigerating electric vehicle", International Journal of Engineering and Advance Technology, 10 (4), pp. 52-58.
[11] Ikram, H., Javed, A., Mehmood, M., Shah, M., Ali, M., & Waqas, A. (2021), "Techno-economic evaluation of a solar PV integrated refrigeration system for a cold storage facility", Sustainable Energy Technologies and Assessments, 44, p. 101063.
[12] Gao, Y., Ji, J., Han, K., & Zhang, F. (2021), "Comparative analysis on performance of PV direct-driven refrigeration system under two control methods", International Journal of Refrigeration, 127, pp. 21-33.
[13] Gurkaynak, Y., Onar, O., & Khaligh, A. (2009), "A photovoltaic-battery powered all-electric rickshaw for the Indian market (No. 2009-01-1306). SAE Technical Paper.
[14] Mulhall, P., Lukic, S. M., Wirasingha, S. G., Lee, Y. J., & Emadi, A. (2010), "Solar-assisted electric auto rickshaw three-wheeler", IEEE transactions on vehicular technology, 59(5), pp. 2298-2307.
[15] Reddy, N. N., & Sarma, D. P. (2012), "Solar powered vehicle", International Journal of Advanced Research in Computer Science and Electronics Engineering (IJARCSEE), 1, pp. 36-39.
[16] Siddique, A. R. M., Zafar, N. B., Rahman, S. S., & Kaiser, S. (2013), "Solar-based rickshaw ambulance for the remote areas of developing countries", In 2013 1st International Conference on Artificial Intelligence, Modelling and Simulation (pp. 381-384). IEEE.
[17] Rhaman, M., & Toshon, T. A. (2014), "Solar powered rickshaw (SPR) can diminish the physical labor of rickshaw puller and improve the power crisis in Bangladesh", International Journal of Engineering and Manufacturing, 4(4), pp. 26-35.
[18] Sameeullah, M., & Chandel, S. (2016, April). Design and analysis of solar electric rickshaw: A green transport model", In 2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS) (pp. 206-211). IEEE.
[19] Reddy, K. S., Aravindhan, S., & Mallick, T. K. (2017), "Techno-economic investigation of solar powered electric auto-rickshaw for a sustainable transport system", Energies, 10(6), 754.
[20] Karim, A., & Shahid, Z. (2018), "Performance and cost analysis of conventional petrol car converted into solar-electric hybrid car", Journal of Energy Resources Technology, 140(3).
[21] Waseem, M., Sherwani, A. F., & Suhaib, M. (2019), "Integration of solar energy in electrical, hybrid, autonomous vehicles: a technological review", SN Applied Sciences, 1(11), pp. 1-14.
[22] Nambisan, P., Bansal, S., & Khanra, M. (2020), "Economic Performance of Solar Assisted Battery and Supercapacitor based E-Rickshaw", In 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020) (pp. 1-6). IEEE.
[23] Dhar, S., Jayakumar, A., Lavanya, R., & Kumar, M. D. (2021), "Techno-economic assessment of various motors for three-wheeler E-auto rickshaw: From Indian context", Materials Today: Proceedings.