MACHINE INTELLIGENCE RESEARCH
ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

MODELLING AND SIMULATION OF A 3-WHEELER ELECTRIC VEHICLE

S. Deepak Kumar[1, *]
Associate Professor, Department of Mechanical Engineering,
SRM University, Delhi-NCR, Sonipat, Haryana-131023, India

Pediredla Rohith[2]
[2]Research Scholar, Department of Mechanical Engineering,
Centurion University of Technology and Management, Viziangaram-535003, Andhra Pradesh.

P. S. V. RamanaRao[3]
[3]Professor, Department of Mechanical Engineering,
Centurion University of Technology and Management, Viziangaram-535003, Andhra Pradesh.

R. Surya Teja[4]
[4]Assistant Professor, Department of Mechanical Engineering,
Centurion University of Technology and Management, Viziangaram-535003, Andhra Pradesh.

R.C. Mohanty[5]
[5]Professor, Department of Mechanical Engineering,
Centurion University of Technology and Management, Bhubaneswar, Jatni, Odisha- 752050

Correspondence Author
E-mail: dr.deepaksahini@gmail.com

Abstract:

Electric mobility has emerged as a key solution for sustainable transportation, particularly in urban and semi-urban regions. In recent years the advancements of Electric Vehicle's technology have highlighted the need for accurate modelling and simulation of electric vehicle (EV) powertrains are essential for evaluating performance, optimizing component selection, and reducing development cost.

This research article presents the modelling and Simulation of a 3-wheeler electric vehicle using MATLAB/Simulink. The complete EV powertrain model comprising the battery, motor, controller, transmission, and vehicle dynamics is developed and simulated under standard drive cycles. Key performance parameters such as battery state of charge (SOC), energy consumption, motor torque, speed, and power are evaluated.

In addition, experimental validation is carried out using real-time data from a commercial 3-wheeler electric rickshaw. The comparative analysis between simulation and experimental results demonstrated close agreement, validating the effectiveness of the proposed model. Thus, in the context of real-time testing, modelling and simulation of EV power-train components play a vital role in developing efficient electric vehicles.

Keywords: Electric Vehicle; E-Mobility; MATLAB; Simulink, Powertrain; Drive cycles

1. Introduction

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

The need of sustainable transportation has increased the demand for efficient Electric vehicles due to their low operating cost, zero emissions, and suitability for urban mobility.

An Electric vehicle is basically a transportation vehicle propelled by an electric motor. A vehicle that is fully or partially driven by electric motors using energy stored on rechargeable batteries can be termed as 'Electric Vehicle' (EV) [1].

The EVs operate on the principle of converting electrical energy into mechanical energy to power the wheels, enabling movement. This process involves a battery that stores electrical energy, an electric motor that transforms this energy into rotational motion, and a control. These are also known as battery-electric vehicles [2].

In recent years, the global shift toward clean and energy-efficient transportation has significantly increased the adoption of electric vehicles (EVs). This transition from conventional fossil-fuel vehicles to electric mobility solutions is referred to as 'E-Mobility'. [3]. Electric mobility solutions cover electric two-wheelers, three-wheelers (e-rickshaws), four-wheelers and buses. This shift is driven by the need to reduce pollution, dependency on oil imports, and carbon emissions, while promoting sustainability and innovation [4].

In Indian market Electric rickshaw, popularly known as 'e-rickshaw' are going more popular especially after 2018. Among various EV categories, 3-wheeler e-rickshaws have gained prominence due to their affordability, low operating cost, and zero tailpipe emissions [5-6].

E-rickshaw is a best alternative of petrol or CNG auto-rickshaws because of their low fuel cost, zero emissions and less human efforts. These vehicles are widely used for short-distance passenger transport, particularly in developing countries [7].

1.1. Electric Vehicle Powertrain Architecture

The EV powertrain components which includes the battery, motor, inverter, and transmission are critical for converting stored electrical energy into efficient, high-torque mechanical movement [8].

Sub-systems of an EV

An Electric Vehicle comprises of several interconnected sub-systems that work together, as shown in Figure 1.

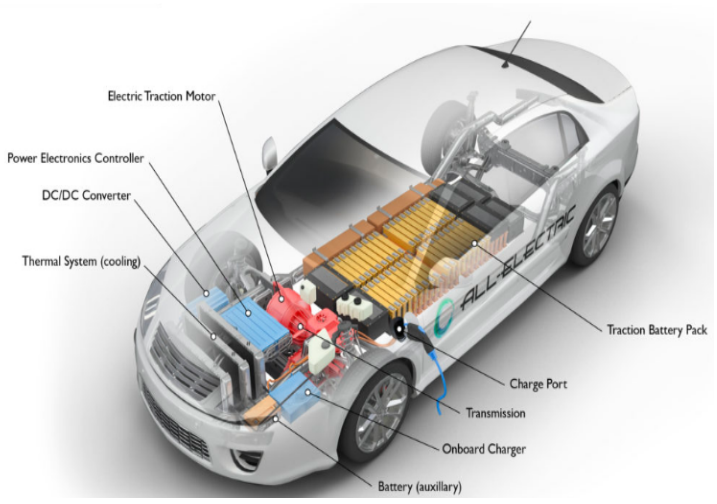


Fig. 1 Electric Vehicle powertrain components

1.2. Functions of EV Powertrain Components

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

- **Battery Pack: Stores electrical energy** (example lithium-ion), Supplies DC power to the motor and auxiliary systems. Determines range and overall energy capacity [9].
- **Battery Management System (BMS)** Monitors and controls battery health, voltage, current, temperature, and State of Charge (SOC).
- **Electric Motor: Converts electrical energy into mechanical energy to drive the wheels.**
  Provides instant torque and regenerative braking capability [10].
- **Controller:** Manages power distribution, motor control, and driver inputs like accelerator/brake.
- **Transmission:** Transfers mechanical power from the motor to the wheels. Typically, a **single-speed gearbox** in most EVs generate high motor torque [11].
- **Regenerative Braking System: Converts kinetic energy during braking into electrical energy. It sends recovered energy back to the battery, improving efficiency [12].**

1.3. Modelling and Simulation strategies for Electric Vehicles

In the context of real-time testing, numerical Modelling and Simulation of Electric Vehicle (EV) power-train play a vital role in developing an efficient electric vehicle and charging infrastructure as it consumes less time and cost [13]. Also, it enhances the overall performance by optimizing the size and configuration of the EV powertrain under different driving conditions [14].

"Simulating an electric vehicle (EV) in MATLAB can be approached through several interconnected components such as the electric motor, battery, vehicle dynamics, and control strategies. Below is an outline for building a comprehensive EV simulation model" [15-16].

Thus, this research article focuses on the modelling and simulation of a 3-wheeler electric vehicle powertrain and its validation through experimental data. The main contributions of this work include realistic drive-cycle-based simulation, performance evaluation of EV components, and comparison with real-time vehicle data.

2. Methodology

The modelling and simulation of electric vehicles play a crucial role in modern vehicle design, analysis, and optimization [17-18]. Further, simulation-based analysis of EV powertrains enables engineers to evaluate vehicle performance under realistic driving conditions without extensive physical prototyping. MATLAB/Simulink provides a powerful environment for integrating electrical, mechanical, and control subsystems [19-20].

2.1. Modelling in MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. The modelling is made through MATLAB/Simulink environment [21-22].

Simulink provides built-in blocks for many of these EV sub-systems and is used in the current work for modeling and simulation of EV models, including battery and motor dynamics [23-25]. In this research work the Optimization of process parameters of an Electric vehicle's sub-systems

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

is carried out in MATLAB -Simulink and the entire simulation system is divided into four subsystems

- The first sub-system contains the vehicle body.
- The second sub-system contains the motor and controller circuit.
- The third sub-system contains the driver input, and
- The fourth sub-system contains the battery pack.

The block diagram showing the significant components of the Electric Vehicle system is depicted in Figure 2.

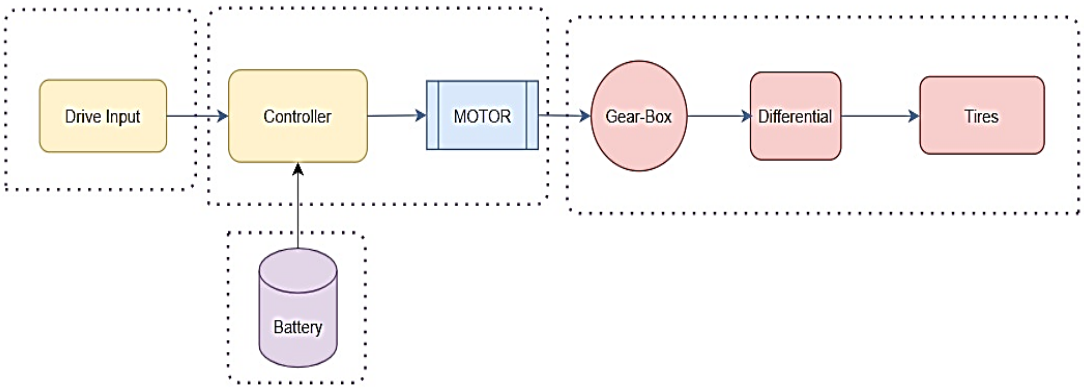


Fig. 2. Block Diagram of the Electric Vehicle System

For a comprehensive simulation, Simulink was used to create block diagrams for each subsystem [26-27].

- Vehicle Dynamics: A subsystem with inputs like throttle, brake, and road conditions [28-29]
- Motor Control: A block that models the torque-speed characteristics of the motor [30].
- Battery System: A block that tracks SoC and delivers current to the motor [31].
- Driver Model: Simulate driver inputs like speed control and braking [32-33].

2.2. Modelling and Simulation of a 3-Wheeler Electric Rickshaw

The block diagram showing the significant components of a 3-wheeler EV is depicted in Fig. 3 and the model of the 3-Wheeler Electric rickshaw vehicle used in this research work is presented in Figure 4.

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

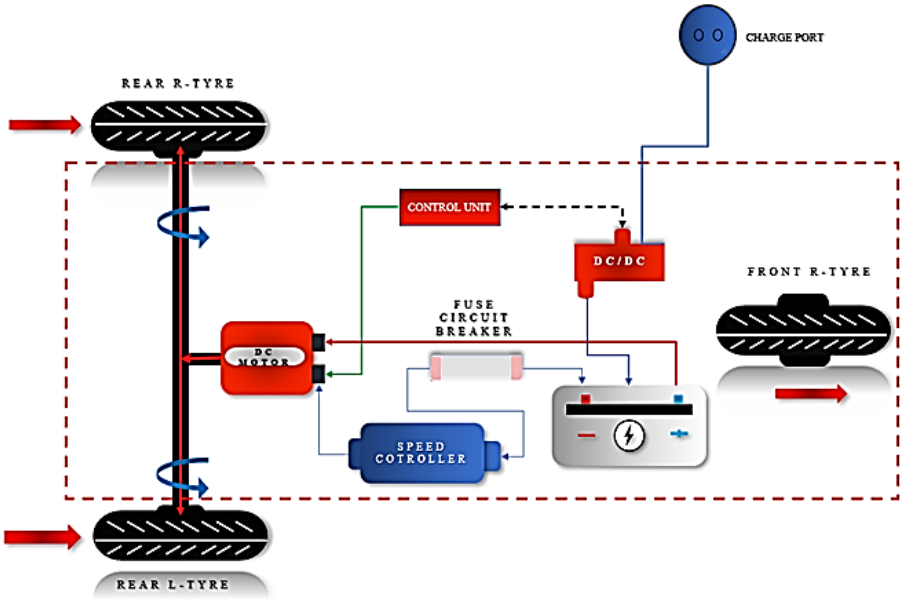


Fig. 3 Block diagram of a 3-Wheeler Electric rickshaw



Fig. 4 Model of a 3-Wheeler Electric vehicle

The electrical system used in this work is an Indian version EV having 48V DC which can run 90– 100 km/full charge, top speed 25 km/hour and the electric motor power ranging from 650-1400 Watts, while the battery takes 8 –10 hrs to become fully charged. Basic seating capacity is driver plus 4 passenger total 5 persons. The specifications of the 3-wheeler electric vehicle used in the present work is presented in Table.1.

Table.1 Specifications of 3-wheeler E-Rickshaw

Technical specifications of 3-wheeler E-Rickshaw	
Battery Type	Lithium Ion 330 V 75 Ah

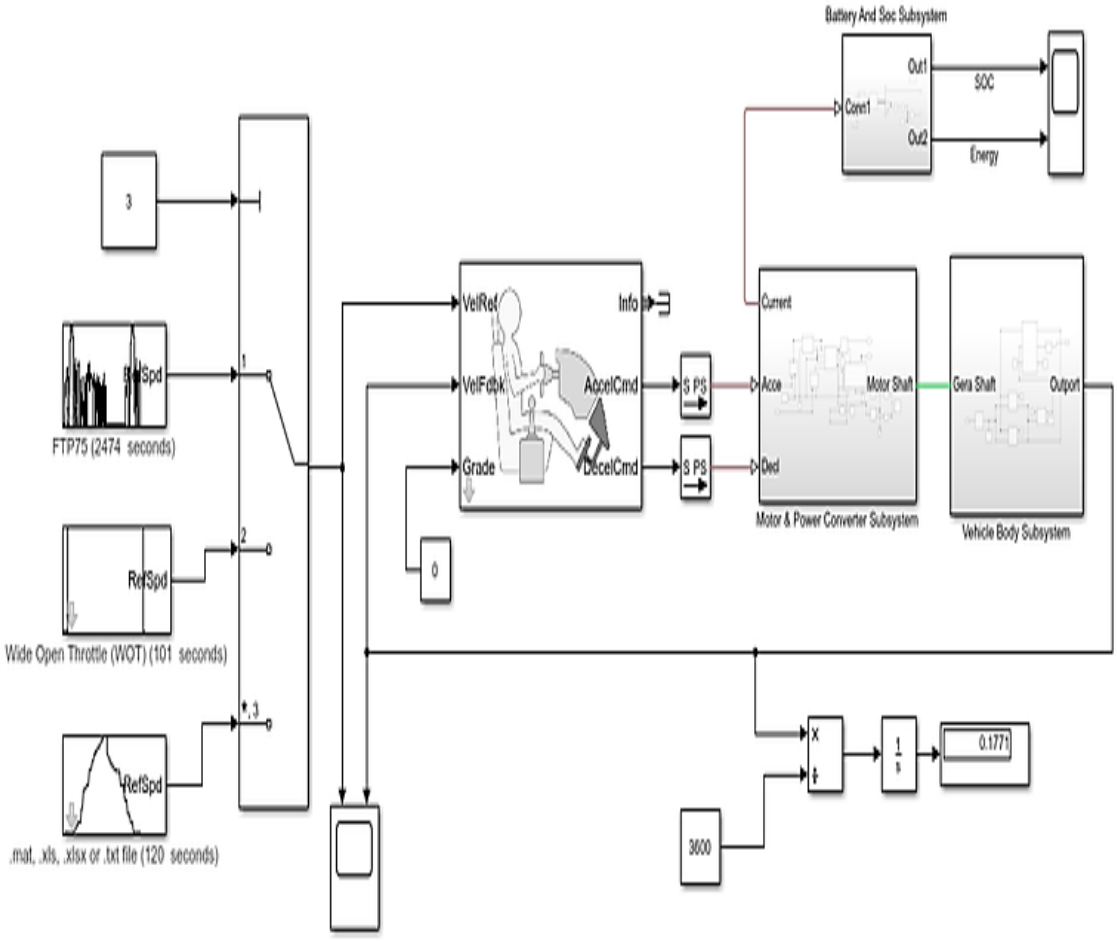
ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

Vehicle kerb weight 260 Kgs	No of wheels per axle 2
Load capacity 340 kgs	Vertical load 3000 N
Vehicle speed 7Kmph	Nominal Voltage 330 V
Driving range 140 km (160 Ah)	Rated Capacity 75 Ah
Frontal Area 91m	
Drag coefficient 5	
Initial SOC % 100	
Internal Resistance 5 ohm	
Wheel radius 306m	

2.3. MATLAB -Simulink Model of 3-wheeler Electric Vehicle

The Simulink Model of a 3-wheeler Electric Rickshaw is presented in Figure 5.

Initially the current flows to DC Motor from the battery through the DC-DC power converter to drive the motor. The required voltage will be controlled in the controller. The Controller will follow the given drive cycle reference and run the motor in the required rpm. Then the motor power is transmitted to the wheels of a vehicle through the gear box. Accordingly, the controller maintains the vehicle speed.



ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

Fig. 5 Simulink Model of a 3-wheeler Electric Vehicle

3. Results and Discussion

Here basically, e-rickshaw is modelled in MATLAB Simulink. In the designed electric rickshaw main blocks are battery, drive cycle, controller, DC Motor, Vehicle body and transmission system. Drive cycle in EV simulation is a standardized speed-versus-time data profile used to model real-world driving behavior. In the current work, drive cycle like FTP75, WOT were analyzed. The output plots of the drive cycle Federal Test Procedure (FTP) are explained below.

3.1. FTP75 Drive Cycle

The electric vehicle was simulated under the FTP-75 urban driving cycle for a duration of 2474 seconds. The total distance travelled was 19.44 km, representing typical stop-and-go city driving conditions. The plot showing the reference speed Vs Vehicle Speed for a FTP75 Drive cycle is presented in Figure 6. Further, the SOC and Energy for FTP75 Drive cycle is shown in Figure. 7

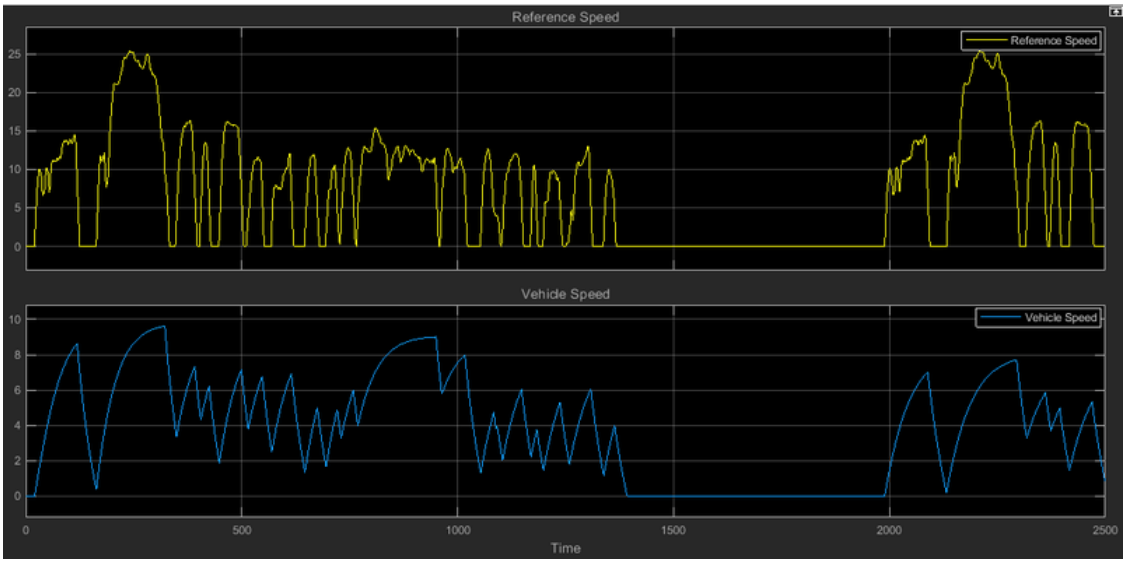


Fig. 6 Reference Speed Vs Vehicle Speed for FTP75 Drive cycle

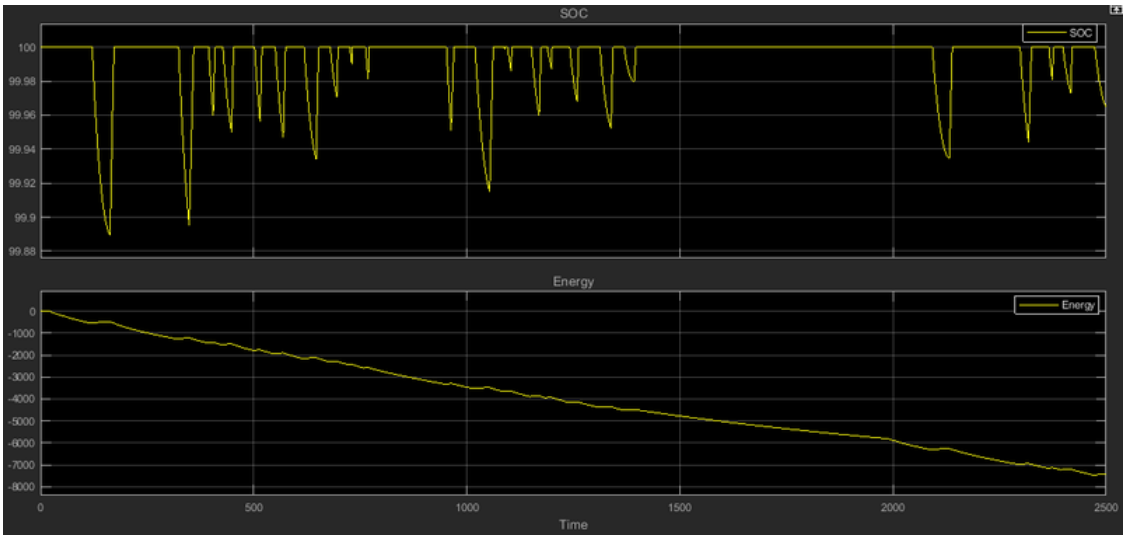


Fig. 7 SOC and Energy for FTP75 Drive cycle

- Reference Speed vs Vehicle Speed: The vehicle speed closely follows the reference FTP-

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

75 speed profile

- Battery State of Charge (SOC): The SOC shows a gradual and continuous decrease throughout the drive cycle. During deceleration, SOC reduction rate decreases, indicating regenerative braking
- Temperature: The motor and controller temperature rise gradually during the drive cycle but remained within permissible limits, confirming the thermal robustness of the EV powertrain under urban driving conditions.

3.2. Experimental Set-up of 3W Electric Vehicle

The Process flow of Assembly of a 3-Wheeler Electric Rickshaw is presented in Figure 8.

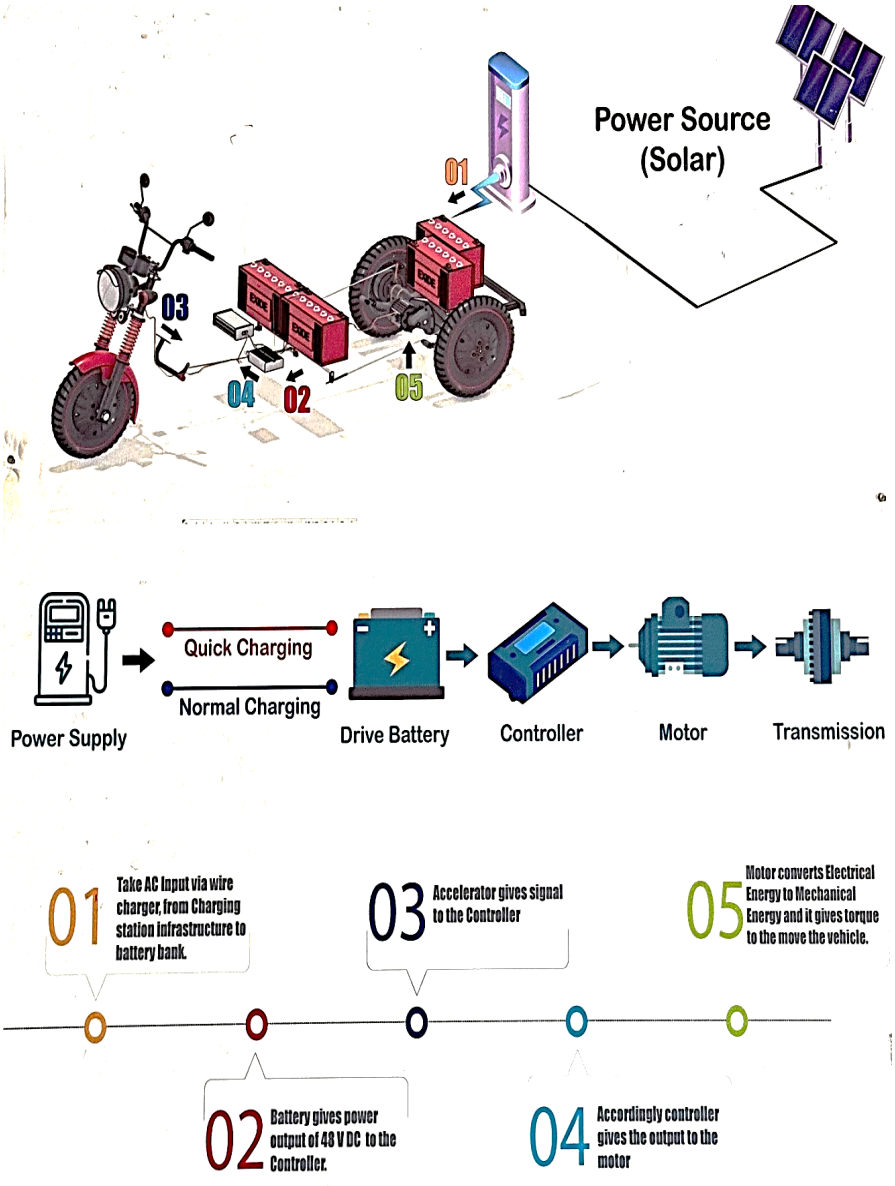


Fig. 8 Process flow of Assembly of an Electric Vehicle Mechanism

Further, the Assembly process of a 3-Wheeler Electric Rickshaw is depicted in Figure 9 below:

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)



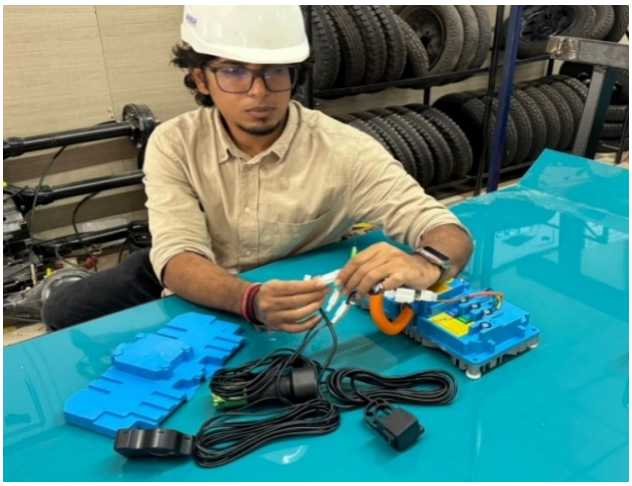
(a)



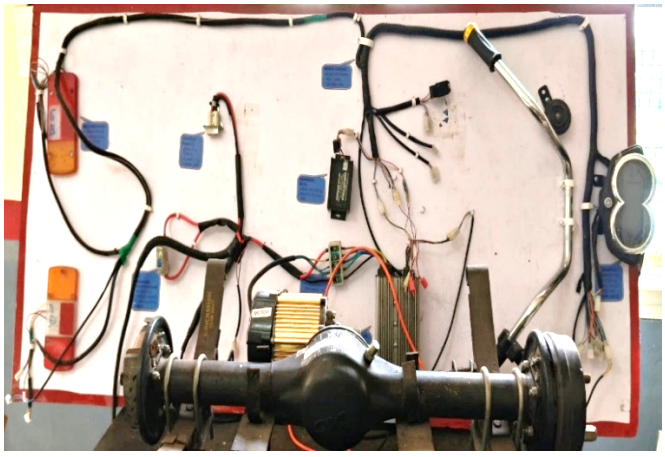
(b)



(c)



(d)



(e)



(f)

Figure 9 (a) Quality inspection of the Electric Vehicle
(b) Electrical wiring and Lighting systems connections of the EV
(c) Assembling Circuit connections in the body panel of EV
(d) Circuit connections of the Controller
(e) Rear Axle Chassis mounted with Motor of the EV
(f) Fixing the Motor to the Rear Axle of the Electric vehicle

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

3.3. Comparison of Experimental & Simulation results of 3-Wheeler E-Vehicle

To validate the simulation model, an experimental study was conducted on a commercially available 3-wheeler electric rickshaw that closely matches the simulated vehicle specifications. The aim was to compare key parameters: speed, torque, and battery state-of-charge (SOC) - under identical drive conditions.

The test conditions of the 3W Electric Vehicle have the specifications: 48V, 100Ah Li-ion, 3000W PMSM

The Speed sensor and GPS for velocity; Torque transducer on motor shaft and the battery management system (BMS) for SOC monitoring. The drive Cycle of Urban stop-go pattern emulating FTP-75 (20 minutes) was analyzed. The comparison of Experimental & Simulation results of 3W EV is presented in Table 2. Further, Comparison of SOC vs. Time and Torque vs. Speed for Simulated and experimental results is presented in Figure 10.

Table. 2 Comparison of Experimental & Simulation results of 3-Wheeler E-Vehicle

Parameter	Experimental Result	Simulation Result	Deviation (%)
Top Speed	54.2 Km/h	55 Km/h	1.45 %
Max. Torque	20.5 Nm	21 Nm	2.38 %
SOC Decrease	14.6 %	13.9 %	4.79 %
Avg. Acceleration	1.47 m/s^2	1.52 m/s^2	3.40 %

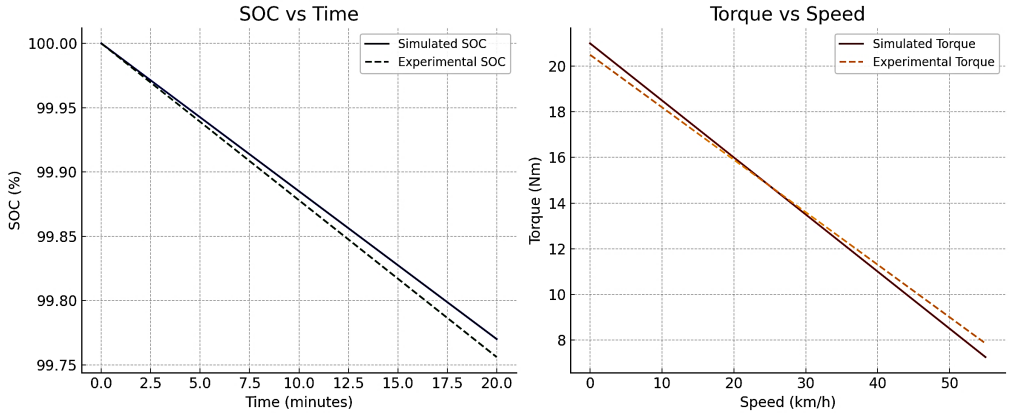


Fig. 10 Comparison of SOC vs. Time & Torque vs. Speed for Simulated and experimental results

4. Summary and Conclusions

The experimental results obtained from a 3-wheeler Electric vehicle are compared with simulation outcomes to validate the developed EV model.

- The experimental data aligns closely with the simulated outputs. The maximum speed and torque measured in real-world tests were within a 5% deviation range from simulation predictions.
- The simulated top speed closely matches the experimental value, indicating **accurate modelling of motor dynamics, drivetrain losses, and vehicle resistance forces.**
- The small deviation demonstrates that the motor torque model and controller behavior are well represented in the simulation.
- The small deviations validate that the Simulink model is an accurate representation of the

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

real-world electric rickshaw.

- A slightly higher deviation is observed in SOC estimation due to simplified battery equivalent circuit model and neglecting temperature-dependent battery losses in simulation.
- However, the acceleration results show good agreement, confirming the validity of vehicle longitudinal dynamics and traction force modelling.
- Overall, al the deviations are below 5%, which is acceptable for EV system modelling.
- The simulation results confirm that the developed simulation model reliably predicts real-world performance

The study demonstrated that the comparison between experimental and simulation results of the 3-wheeler electric vehicle shows deviations within 5% for key performance parameters, validating the accuracy and reliability of the developed EV modelling and simulation framework.

ACKNOWLEDGEMENT

The authors greatly acknowledge the support received from *Gram-Tarang Technologies*, for providing their support for conducting experimental work at the *Electric Vehicle* Manufacturing and assembly unit at **Centurion University of Technology and Management Andhra Pradesh.**

REFERENCES

1. Ahmet Onur Kiyakli and Hamit Solmaz. (2018). Modeling of an Electric Vehicle with MATLAB/Simulink. International Journal of Automotive Science and Technology, 2(4): 9-15.
2. Pediredla Rohith, S. Deepak Kumar, P.S. V. Ramana Rao, Rampalli Surya Teja, P. A. Sunny Dayal, & Mir Sadat Ali. (2024). An Overview of Electric Vehicles. Educational Administration: Theory and Practice, 30(1), 6072 - 6079. ISSN: 2148-2403. https://kuey.net/index.php/kuey/article/view/9488
3. Pediredla Rohith, S. Deepak Kumar, P.S.V. Ramana Rao, Suman Kumar and Nihar Kanta Sahu, (2023). Principles of Electric Vehicles: Components and Types, Indian Journal of Natural Sciences, IJONS Journal, Vol.14 (81), pp.1-8, ISSN: 0976 – 0997.
4. Deepak Kumar, S., Arun Manohar, G., Surya Teja, R., Ramana Rao, P.S.V., Mandal, A., Behera, A. and Srinivasa Rao, P. (2023). Smart Manufacturing Technologies in Industry 4.0. In Intelligent Manufacturing Management Systems (eds K. Muduli, V.P. Kommula, D.K. Yadav, M. Chithirai Pon Selvan and J. Kandasamy). https://doi.org/10.1002/9781119836780.ch2
5. Abagnale, C., Cardone, M., Iodice, P., et al. (2016). Design and Development of an Innovative E-Bike, Energy Procedia, 101: 774-781.
6. Hua, W., Mullen, D., Wahid, A., et al. (2024). An Overview of Artificial Intelligence for Electric Vehicle Energy Systems Integration. In: Nowaczyk, S., et al. Artificial Intelligence. ECAI 2023 International Workshops. ECAI 2023. Communications in Computer and Information Science, vol 1948. Springer, Cham.
7. Shivangi Kaushik, (2019). Modeling and Simulation of Electric Vehicle to Optimize Its Cost and Range, International Journal of Engineering and Advanced Technology, vol. 8(6), pp.415-419.

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

8. Khurana, A., Kumar, V. V. R., & Sidhpuria, M. (2020). A Study on the Adoption of Electric Vehicles in India: The Mediating Role of Attitude. Vision, 24(1): 23-34.
9. Bharathidasan, M., Indragandhi, V., Suresh, V., *et al.* (2022). A review on electric vehicle: Technologies, energy trading, and cyber security, Energy Reports, vol. 8: 9662-9685.
10. Manzetti, S., and Mariasiu, F. (2015). Electric vehicle battery technologies: From present state to future systems. Renew. Sustain. Energy Rev. 51: 1004–1012.
11. Gupta, A.R., Gupta, R., Saurav, Tiwari, A., Purohit, R. (2021). Overview of Electric Vehicle: Opportunities and Challenges with Smart Grid. In: Gupta, O.H., Sood, V.K. (eds) Recent Advances in Power Systems. Lecture Notes in Electrical Engineering, vol 699. Springer, Singapore.
12. Vighnesh, C., Manoj, V., and Rao, B.B. (2022). A Review of Electric Vehicle Technology Development. International Journal of Research Publication and Reviews, 3(10):594-600.
13. Kumar, A. (2024). A comprehensive review of an electric vehicle based on the existing technologies and challenges. Energy Storage, 6(5), e70000.
14. Sanguesa, J. A., Torres-Sanz, V., Garrido, P., Martinez, F. J., & Marquez-Barja, J. M. (2021). A review on electric vehicles: Technologies and challenges. Smart Cities, 4(1), 372-404.
15. Sun X, Li Z, Wang X, Li C. (2020). Technology Development of Electric Vehicles: A Review. *Energies*. 13(1):90. https://doi.org/10.3390/en13010090
16. Chan, C.C. (2002). The state of the art of electric and hybrid vehicles. Proc. IEEE 2002, 90, 247–275.
17. Sahini, D. K., Ghose, J., Jha, S. K., Behera, A., & Mandal, A. (2020). Optimization and Simulation of Additive Manufacturing Processes: Challenges and Opportunities – A Review. In K. Balasubramanian & V. Senthilkumar (Eds.), *Additive Manufacturing Applications for Metals and Composites* (pp. 187-209). IGI Global. https://doi.org/10.4018/978-1-7998-4054-1.ch010
18. Deepak Kumar, S., Dewangan, S., Jha, S.K., Parida, S.K., Behera, A. (2021). 3D and 4D Printing in Industry 4.0: Trends, Challenges, and Opportunities. In: Bag, S., Paul, C.P., Baruah, M. (eds) Next Generation Materials and Processing Technologies. Springer Proceedings in Materials, vol 9. Springer, Singapore. https://doi.org/10.1007/978-981-16-0182-8_43
19. Statista. (2022). Electric Vehicles Worldwide.
20. Goel, S., Sharma, R., and Rathore, A. K., (2021). A review on barrier and challenges of electric vehicle in India and vehicle to grid optimization. Transportation Engineering 4: 100057.
21. Khalid, M.R., Alam, M.S., Sarwar, A., and Asghar, M.S.J. (2019). A Comprehensive review on electric vehicles charging infrastructures and their impacts on power-quality of the utility grid, eTransportation, 1(100006).
22. Macharia, V.M., Garg, V.K., Kumar, D. (2023). A review of electric vehicle technology: architectures, battery technology and its management system, relevant standards, application of artificial intelligence, cyber security, and interoperability challenges. IET Electr. Syst. Transp. p.25 (e12083). https://doi.org/10.1049/els2.12083.

ISSN:2731-538X | E-ISSN:2731-5398
Vol. 20 No. 01 (2026)

23. Halim. A. *et al.* (2024). Electric vehicles: a review of their components and technologies. International Journal of Power Electronics and Drive systems. Vol. 13(4):2041-2061. http://doi.org/10.11591/ijpeds.v13.i4.pp2041-2061
24. Un-Noor F, *et al.* (2017). Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development. Energies. 10(8):1217. https://doi.org/10.3390/en10081217
25. Slough, J., Belcher, M., Tsui, T., and Bhattacharya, S. (2021). Modeling and Simulation of Electric Vehicles Using Simulink and Simscape. *2021 IEEE 94th Vehicular Technology Conference (VTC2021-Fall)*, Norman, OK, USA, 2021, pp. 01-06.
26. Rohith Pediredla, S. Deepak Kumar, P. S. V. Ramana Rao, *et al.*, (2024). Speed Control of Induction Motor Using Hippopotamus Optimizer Based Sliding Mode Controller with SVPWM Method for Electric Vehicle, In: International Conference on Sustainable Power & Energy (ICSPE), Raigarh, India, 2024, pp. 1-7. IEEE Xplore https://ieeexplore.ieee.org/document/10924390
27. M. Abuaddous, Rohith Pediredla, S. Deepak Kumar, P. S. V. Ramana Rao, *et al.*, (2024). Direct Torque Control of SRM Drive for Electric Vehicle by Using ANN-LSTM Controllers, In: International Conference on Sustainable Power & Energy (ICSPE), Raigarh, India, 2024, pp. 1-6. IEEE Xplore. https://ieeexplore.ieee.org/document/10924388
28. H. Al-Mattarneh, Rohith Pediredla, S. Deepak Kumar, P. S. V. Ramana Rao, *et al.*, (2024). Efficient Energy Management System of Grid Connected wind-PV based EV Charging Station Using Novel Aggregated Control Method, In: International Conference on Sustainable Power & Energy (ICSPE), Raigarh, India, 2024, pp. 1-6. IEEE Xplore. https://ieeexplore.ieee.org/document/10924342
29. Muratori, M., *et al.* (2021). The rise of electric vehicles —2020 status and future Expectations. Progress in Energy, 3(2), 022002. https://doi.org/10.1088/2516-1083/abe0ad
30. Khurana, A., Kumar, V. V. R., & Sidhpuria, M. (2020). A Study on the Adoption of Electric Vehicles in India: The Mediating Role of Attitude. Vision, 24(1), 23-34. https://doi.org/10.1177/0972262919875548
31. Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. Journal of Cleaner Production, 253, 119911. https://doi.org/10.1016/j.jclepro.2019.119911
32. Angeline, P.S., and Rajkumar, M.N. (2020). Evolution of electric vehicle and its future scope, Materials Today: Proceedings, Vol. 33 (7), pp. 3930-3936, 2020. https://doi.org/10.1016/j.matpr.2020.06.266
33. Dr. Deepak Sahini, Rohith Pediredla, Dr. P. S. V. Ramana Rao, (2024). In: "Electric Vehicles- Technology, Trends and Future Prospects", Academic Guru Publishing House, ISBN: 978-81-974780-8-6.