

Rajat Kumar Samantaray^{1*}, M. Vinay Kumar², Pramod Kumar Gouda³, Ashwin Kumar Sahoo¹, Bibhuti Bhusan Rath³

J. Electrical Systems 21-2 (2025): 195-207

Regular paper

Electric Vehicles: A Comprehensive Assessment of Batteries and Charging Technologies



**Journal of
Electrical
Systems**

The transportation sector is essential for the socio-economic growth of any country. Vehicular travel is generally propelled by internal combustion engines (ICE) powered by fossil fuels in earlier days, causing an increase in air pollution, production of greenhouse gases leading to several health issues, global warming, glacier melting, etc., Various challenges associated with the usage of these vehicles and with development in technology led to development of an alternative mode of transportation system; hence a promising solution obtained was electric vehicles (EVs). These EVs are gaining widespread popularity due to numerous advantages like quieter operation, reduction in emission of greenhouse gases, emission from tailpipe zero, minimum maintenance costs, encouragement from government for its usage by offering subsidies, better driving experience & performance, and more importantly power can be generated during braking periods i.e., regenerative braking and reduction in dependency on fossil fuels, whereas challenges associated with this technology exists as well, like high initial cost, limited range of distance for single charge, longer time for recharging, limited life span of the battery, battery performance depending on the operating conditions, etc. The transition from the usage of conventional ICE vehicles to EV requires a thorough analysis of EVs. The paper aims to put forward a comprehensive review on rechargeable batteries of various types used for EVs and charging technologies like conductive charging, wireless charging, battery swapping etc., used for EVs.

Keywords:Charging Technologies, Electric Vehicles, Grid Integration, Power Electronics, Rechargeable Batteries.

1. Introduction

Transportation is essential in our daily life to achieve various needs, most importantly, earning our livelihoods. In earlier days, the mode of transportation used to be by walking, Later, after the invention of wheels, vehicles propelled by animals or human beings were the preliminary phase of transportation. With progress in technology, the propulsion of vehicles was replaced by internal combustion engines (ICE), which are energized by fossil fuels. ICE-built vehicles are the major source for various modes of transportation like roadways, airways or waterways. Fossil fuels, though used widely in transportation, hinders its usage due to lot of disadvantages, like hike in the cost of fossil fuels, combustion of fossil fuels leads to the generation of CO₂, CO, SO₂, N₂O, hydrocarbons, etc., leading to various environmental issues like air pollution, water pollution, causing acid rains, change in climate temperature, global warming, melting of glaciers etc., energy crisis, greenhouse gases emissions leading to global warming [1-3], also since these are non-renewable in nature, they may get depleted soon due to upsurge in its usage. Transportation segment is

* Corresponding author: ¹Rajat Kumar Samantaray, Department of Electrical Engineering, C.V. Raman Global University, Bhubaneswar, Odisha, India-752054, Email: rajat.samantaray@gmail.com

²Department of Electrical & Electronics Engineering of GMR Institute of Technology, Rajam, Andhra Pradesh, India-532127

³Department of Electrical & Electronics Engineering of Aditya Institute of Technology & Management, Tekkali, Andhra Pradesh, India-532201

the major producer of greenhouse gases (GHG) which is the root cause for various ill effects of the environment.

To safeguard the environment, health and to store the reserves of fossil fuels for the generations to come, the conventional ICE for propulsion of vehicles is replaced by electrical motors, and these vehicles are electric vehicles (EVs), powered by electrical energy, which is supplied by rechargeable batteries. The battery of the EVs is the major part and then follows the traction motor which is required for its propulsion. The powertrain of an EV constitutes a motor and batteries whereas a conventional vehicle comprises of ICE for propulsion followed with transmission system [5-9]. For propulsion of EVs, motors are selected based on characteristics like higher power density, better performance.

With respect to energy storage systems, for supplying electrical power to the motor, Lithium-ion (Li-ion) batteries have a better edge and are mostly used. When compared to its competent Lead acid batteries, Ni-Cd batteries have their own limitations. EVs come up with number of benefits when compared with the ICE vehicles, almost nil tail pipe emission, zero emission, leading to better air quality, lesser number of moving parts leading to decrease in maintenance costs, better efficiency, good acceleration, reduced fossil fuel dependence and quitter operation. Hence, governments of many countries are planning to roll out ICE vehicles and add EVs to the fleet of transportation.

Though EVs have good number of advantages, still there exists few limitations like the upfront cost of EVs is more than conventional ICE vehicles, the driving range is limited to a maximum of 200 km to 300 km for a single charge even for the best EVs, concerns with respect to charging infrastructure, like cost of installation, land cost, charging time is more and it ranges from 20 minutes to few hours, degradation of battery with time leads to decrease in driving range, still more charging time is required when compared to a newer one and its very expensive for replacement of older batteries, etc., that hampers their usage in large. With the above-mentioned pros and cons in usage of EV, the sales in EV have gone up globally, figure 1 below depicts the sales of EV worldwide quarterly.

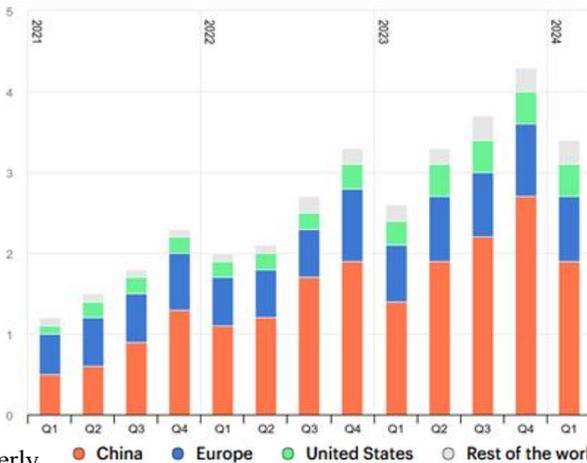


Fig. 1: Quarterly EV sales Globally

The increase in sales suggests the transition of customers from conventional ICE vehicles to EVs is in rise [10-11].

The quantitative & qualitative observations of various battery technologies and various charging technologies will help researchers working in EV further improve the performance of EVs followed by more customers using the EVs. This paper aims to review prospects, opportunities, and challenges of batteries and charging stations for application in EVs. The paper structure is as follows, different vehicles used for transportation is discussed in section II, section III briefs about electric vehicles used for transportation, various batteries used in electric vehicles are presented in section IV, various charging technologies for electric vehicles are described in section V and finally the paper is concluded in section 6.

2. Vehicles

Large section of the transport segment [12-14] is currently occupied by the vehicles which are propelled by ICE; these are the major sources of air pollution, thus causing change in climate and energy sustainability [15-18]. This huge problem can be overcome by the introduction of EV into the transport segment, hence provides an alternative solution for transportation to overcome various issues faced due to usage of ICE vehicles. An ICE vehicle burns the gasoline (fuel) in an ICE whereas an EV is powered by electrical energy delivered by a rechargeable battery. The classification of vehicles is depicted in figure 2 below.

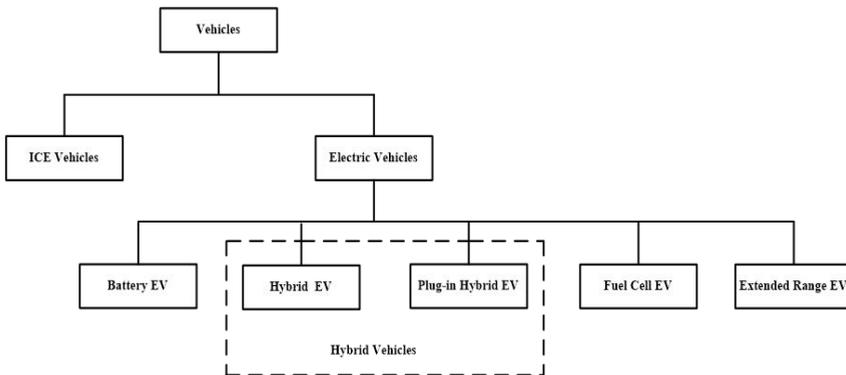


Fig. 2: Classification of Vehicles

The costs per km run of a conventional ICE vehicle is given as:

$$\frac{\text{Per Litre Fuel Cost}}{\text{Range/Total Capacity of the Tank}} \quad (1)$$

The cost per km run of an EV is given as:

$$\frac{\text{Electric Cost per Unit} \times \text{Power} \times \text{Duration of Charge}}{\text{Range of Travel with Single Charge}} \quad (2)$$

A wide comparison of various characteristics like gas, emission, regenerative power, moving parts, efficiency vibrations and production of torque for a conventional ICE vehicle with respect to an EV is listed below in Table 1.

Table 1: Comparison of ICE Vehicles with EV

Characteristics	ICE Vehicle	EV
Gas Emission	More	Very Less

Power Regeneration	Not Possible	Possible
Moving Parts	More	Less
Efficiency	Low	High
Vibrations	Medium	Low
Torque Produced when Stationary	Zero	Maximum

3. Electric Vehicles

The power source for an EV is electrical energy which is fed by rechargeable batteries. The architecture of an EV [19-23] is depicted in figure 3 below.

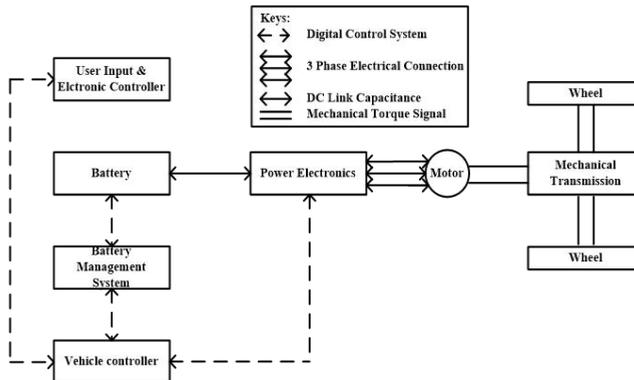


Fig. 3: Architecture of Electric Vehicle Powertrain

Wide comparison of various characteristics like energy source arrangement, energy storage, challenges, advantages, dis-advantages for different types EVs [24-28] is listed below in Table 2. The architecture of different HEV is shown in figure 4.

Table 2: Comparison of various characteristics for different EVS.

Characteristics	EV	HEV	PHEV	FCEV
Energy Source Arrangement	Electricity charging Station	Electrical Power, Refueling Station	Electrical Charging Station & Refueling station	Hydrogen cylinder & refiner, Refilling Station
Energy Storage	Battery, Flywheel, Ultra capacitor	Fuel chamber, Battery, Flywheel, Ultra capacitor	Fuel chamber, Battery, Flywheel, Ultra capacitor	Fuel cell, Ultra capacitor, Battery
Challenges	Battery Size & battery weight, Charging Station infrastructure	Battery Size & battery weight, Components of ICE	infrastructure of Charging Station, Battery Size & battery weight & ICE	Fuel cell cost, Hydrogen storage, Conditioning and refilling Infrastructure
Advantages	Quiet, Zero emission, Silent operation, Independence from Fossil fuels	Less emission, Economics, driving range is long, more Reliable	Driving range extended, fuel efficient, V2G or G2V power transfer capable	Highly efficient, Ultra-low emission, costlier, Competent driving range, Reliable
Dis-Advantages	Driving range is limited, recharging time is more, Poor response	System is Costly & Complex, Huge, more Component	initial cost is high, more complex, Influence on grid	Response is Slow, Not commercialized, Electronic controller is sophisticated

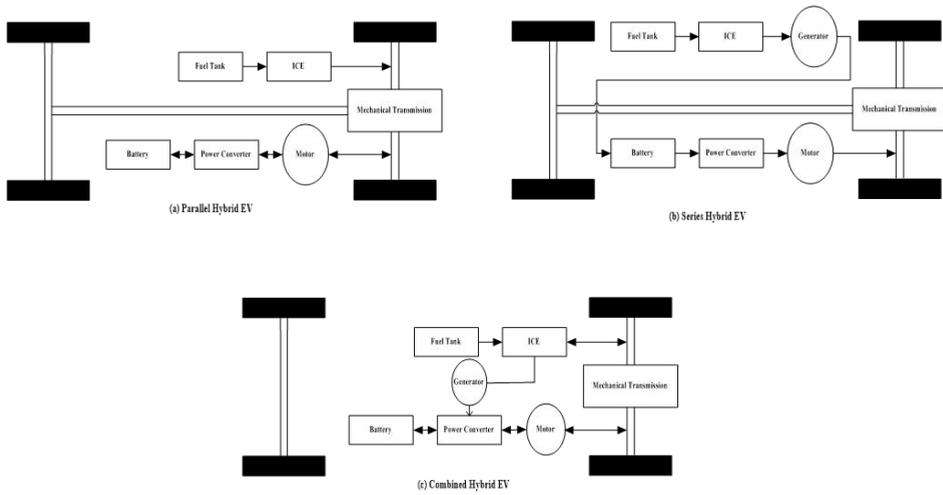


Fig. 4: Layout of Hybrid (a) Series, (b) Parallel, (c) series-parallel (Combined) EV

4. Batteries For Electric Vehicles

A battery, which is constituted by interconnection of number of electrochemical cells, is like a heart for an EV, it converts the stored chemical energy and delivers electrical energy to motor for propulsion of an EV. Any transients in power reduce the lifetime dramatically. The life span for a battery is around 10 ~ 15 years. The energy density of a battery determines the cost and driving range of EV [29-32].

State of charge (SOC) determines the functioning of battery. During the design of an EV, capacity of a battery (Ah), energy (kWh) and SOC should be taken into consideration.

SOC of a battery is given as:

$$SOC_0 = SOC_{Bat0} - \frac{\int_0^T P_{Bat}.dt}{E_{Bat}^{Max}} \quad (3)$$

Here, the battery initial SOC is SOC_{Bat0} , power is ' P_{Bat} ', battery maximum energy is ' E_{Bat}^{Max} '. The allowable limit of battery state of charge ranges from 0.2 to 1.0 for efficient operation, battery lifetime reduces if state of charge falls below this range. Numerous types of batteries are available in the market. Amongst them lithium-ion batteries are mostly used in EVs due to number of advantages like better performance even at higher temperature, energy density is high, specific energy is high, specific energy is high, specific power is high having a long battery life, can be charged quickly and more importantly can be recycled. There are different rechargeable batteries available in the market and the classification of batteries is shown in figure 5.

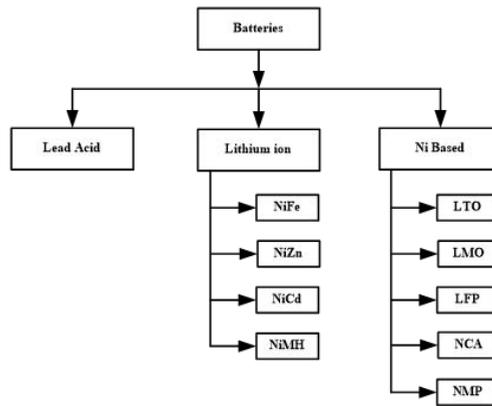


Fig. 5: Classification of Batteries

Lead-acid are the oldest batteries with a wide range of applications, used for higher power applications, are efficient, safe, reliable and less in cost when compared to other batteries. These batteries suffer from few disadvantages like life span is less than 1000 cycles, its working is temperature dependent, specific energy density is low around 30 Wh/kg ~ 40 Wh/kg.

Table 3: Advantages and disadvantages of various types of batteries.

Battery	Advantages	Dis-advantages
Lead Acid	Cost is less when compared with other types of batteries, Advanced technology, Available in mass production.	Low Power and low Energy density, Life reduces when operated at low SOC, Maintenance is required.
Lithium-Ion	Energy density is double as compared to NiMH batteries, specific energy is high and specific power is high, Battery life is long around 1000 cycles, good performance even at higher temperature.	Cost is more; Recharging time is more
NiMH (Nickel-Metal Hydride)	Energy density is double when compared to lead acid battery, can be recycled, Wide range of operating temperature, high specific energy and specific power, can be operated safely at higher temperature	During higher loads life span reduces by 200-300 cycles, Bad memory effect
Ni-Cd (Nickel-Cadmium)	Life span is long, Recyclable, battery can be discharged completely without getting damaged.	Very Expensive, harmful if cadmium is not disposed properly.

Lithium-ion batteries also find their applications in EVs as they operate satisfactorily even at higher temperatures, energy efficiency is high, discharge rate is low, energy storage capacity is high. Nickel-based batteries are mostly used in EVs. Longer life span of NiMH battery, in order of 2000 cycles, charging discharging efficiency of 92%, 1000 W/kg power density maximum and 120 Wh/kg energy density, encourages its application in EVs. Ni-based batteries suffer from a few drawbacks like they are expensive, production of more heat during operation, self-discharging is high and required additional controls are required to control losses. The advantages and disadvantages of Lead Acid batteries with respect to other batteries [33-36] are briefed in Table 3.

Characteristics like efficiency, life span, energy density, power density, operating voltage for various types of batteries used in EVs are summarized in Table 4 below:

Table 4:A summary of various modes of charging

Characteristic	Lead Acid Battery	Li-Ion Battery	Ni-Cd Battery
Cost	Less	More	Less
Nominal Voltage	2V	3.6V	1.25V
Life Cycle	200 - 300	500 - 1000	1500
Power Density	180	1800	150
Energy Density	30 - 50	110 - 160	45 - 80
Overcharge tolerance	High	Very Low	Moderate
Self-Discharge	Less	Very Less	Medium
Operating Temperature	-20°C to 60°C	-20°C to 60°C	-40°C to 60°C
Efficiency	85% - 90%	98% - 100%	95%
Thermal Stability	Less Stable	More Stable	Less Stable

The characteristics of various lithium-based batteries [37-40] are summarized in Table 5 below.

Table 5: Characteristics of various lithium-based batteries

Battery	Life Span (hrs)	Nominal Voltage (V)	Charge (c)	Specific Energy (Wh/Kg)	Discharge (c)
LNO	>300	3.6 - 3.7	1	150 - 200	1
LFP	1000 - 2000	3.2 - 3.3	1	90 - 130	1
NMC	1000 - 2000	3.8 - 4.0	0.7 - 1	150 - 200	1
LMO	300 - 700	3.7 - 4.0	0.7 - 1	100 - 150	1
LCO	500 - 1000	3.7 - 3.9	0.7 - 1	150 - 200	1
LTO	3000 - 7000	2.3 - 2.5	1	70 - 85	10
NCA	500	3.6 - 3.65	0.7	200 - 260	1

5. Charging Technologies for Electric Vehicles

The crucial factors that hinder the adoption of EVs to the transport segment are batteries charging, location for charging points and the time duration for charging. The EVs battery charging is classified according to the power type i.e., AC or DC, level of voltage, single phase or three phase charging, conductive charging or wireless charging. The EVs charging infrastructure is controlled by two standards, namely the International Electro technical Commission (IEC) 61851 standard and the Society of Automotive Engineers (SAE) standard J1772. The former standard is followed in Europe and other parts of the world whereas the latter is followed in North America. The general method of battery charging is conductive charging, the EV charging technologies classification [41-44] is shown in figure 6 below.

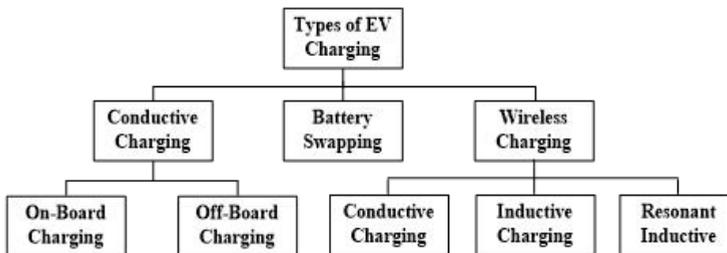


Fig. 6: Classification of EV Charging Technologies

The EV charging classifies as per IEC 61851 standard [45-46] to four modes.

The basic mode of charging is Mode-1, which is done at residential places, charging is left overnight, here vehicle and the charging station doesn't have any communication amongst them. Protection features are included in Mode-2 charging standard, the operating power is in range of 3.7kW-7.4kW, it is well suited for residential and semi commercial applications. Mode-3 application is dedicated to electric vehicle supply equipment having a communication between charger and EV. The power operating capacity is in range of 3.7kW to 44kW. The charging in this category will be semi fast, applicable for commercial purposes.

In Mode-4, the DC power is transferred to battery directly, the operating power is above 140kW, this method allows quickest recharge of the battery. The charging time period will be less than an hour. SAE J1772 standard classifies charging to three levels with respect to location, charging time, charging rate, equipment, Interference with power grid and cost.

The Level-1 charging deals for residential application with a single-phase operating voltage of 120V and a power of 1.9kW and longer charging time around 11 hrs. The Level-2 charging works for both residential and public with a single phase, operating voltage in the range of 210V to 240V and a power of 2.5kW to 19kW and quicker charging time around 4 to 8hrs. The Level-3 charging is about DC power transfer directly to the EV battery and eliminating On-board charger, with quickest charging time to less than 4hrs.

The level-2 application suits well for the parking places, workplace and commercial places. The Level-3 deals with DC power operation application and is the quickest charging among all the three levels. This is well suited for highway applications [47-49].

As per IEC 61851 standard, various modes of charging are briefed in Table 6 below. Table 7 below lists various chief standards for EV charging structures.

Table 6: A summary of various modes of charging.

Modes of Charging	Current (A)	Voltage (V)	Phase	Power (kW)
Mode-1	16	230 - 480	AC-1Φ, AC-3Φ	3.8 - 7.6
Mode-2	32	230 - 480	AC-1Φ, AC-3Φ	7.6 - 15.3
Mode-3	32 - 250	230 - 480	AC-1Φ, AC-3Φ	608 - 120
Mode-4	250 - 400	230 - 480	DC	>150

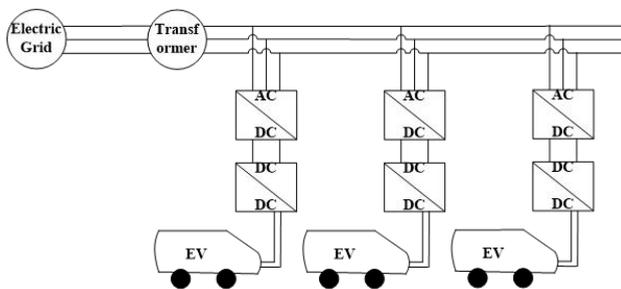


Fig. 7: EV Charging Station Schematic Having Common AC Bus-Based system

Table 7: Leading standards for EV charging structures.

Standards	Statement
SAE J2344	Electrical safety guidelines
SAE J2894/2	Requirements for power quality
SAE J1772	Conductive charger coupling of AEVs and HEVs
SAE J3068	Three phase Power transfer system for EV using AC capable coupling
SAE J2847/1	Communication between EV and grid
IEC 60038	Standards for voltage charging applications
SAE J2931/7	PEV communication security
IEC 60064-1	Low voltage supply charging equipment installation coordination
IEC 62196	EV conductive charging components standards
IEC 61851	Charging stations safety related specifications
IEC 62752	Cable control and protection devices standards
ISO 17409	Connection between EV and external energy source specifications
ISO 15118	V2G communication protocols standards
NEC 625	Off-board EV charging system safety measures
UI 2231	EV charging circuits and charging stations equipment's protection device
IEEE 519-1992	Electrical power system harmonic control
IEEE 1547	Distributed resources interconnecting with electrical power systems standards
P1547, P2100.1	Various aspects of grid connected DERs and charging System Standardization

This charging architecture will be costlier, complex, and number of power transformation phases, leading to reduced efficiency. The transformer on the grid side feeds the required voltage to the AC bus. A three-phase AC bus system is depicted in figure 7.

The number of power conversion stages are eliminated by having a common DC bus-based system. This system is depicted in figure 8 below.

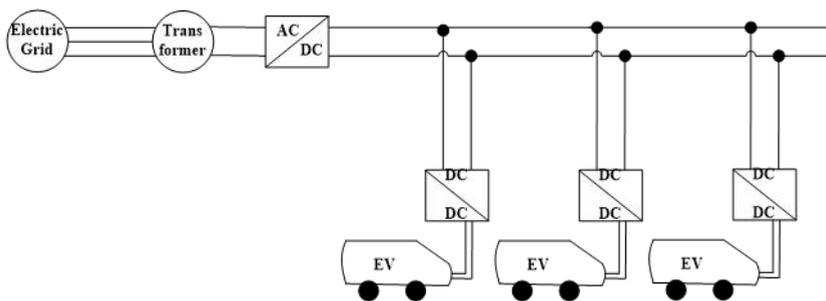


Fig. 8: Connections of DC Bus-Based EV Charging Station

The grid power is converted to DC using a rectifier, in a common DC bus-based system and thereafter each EV is connected to an individual DC-DC converter. When matched to AC bus schematic, the DC bus-based system is cost effective, more efficient, good performance and more flexible. The DC bus system can be fed by renewable energy source or energy storage systems. The AC and DC bus-based system advantages and disadvantages are listed in table 8 below.

Table 8: Features of AC bus system and DC bus system.

Architecture	Advantages	Disadvantages
AC Bus System	Mostly available with full technology Protection devices less in complexity Can be used directly with loads Scalability and Stability is high Control and switching techniques are reliable	More converters reduce efficiency Costlier due to number of converters Fast chargers require additional converters to avoid harmony Complex to integrate renewable sources
DC Bus System	More efficient due to less components Simple in control Low cost and flexible Simple to integrate renewable sources Frequency disturbance is low	Increase in energy sources leads to complexity Protection system required for sudden changes in load Server system required for central converter due to more power handling

AC & DC bus-based systems for EV charging stations are considered AC micro grid and DC grid generally sourced with DC power or a few renewable energy sources. This architecture consists of an AC bus and a

DC bus, Transformer to change the AC voltage level, converters and inverters, is depicted in figure 9 below.

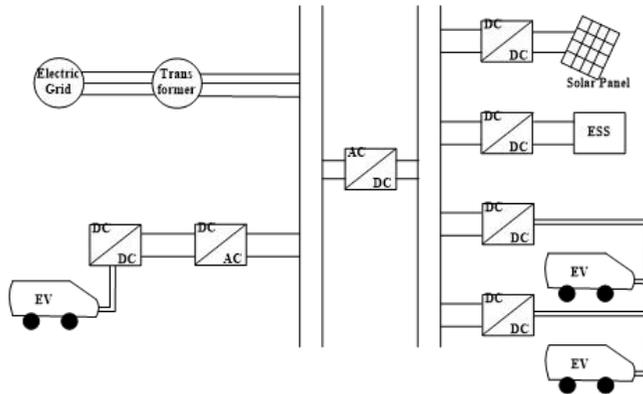


Fig. 9: EV Charging Station Connections for Common AC & DC Bus-Based system

This architecture allows the functioning of both DC and AC charging simultaneously. AC and DC buses can be linked by a single bidirectional converter called as interlinked converter. Energy balance on both the buses can be obtained using this interlinked converter for load requirements. This bus system is flexible and reliable. Bidirectional DC-DC converter aids in discharging V2G operation and is connected amongst the EV and the DC bus.

6. Conclusion

Due to worldwide continuous R & D by academia, industry and government, EVs are slowly and steadily replacing conventional ICE vehicles as they provide promising solutions to various issues caused by ICE vehicles and in near future all the ICE vehicles will be switching over to more and more EVs. Even though government of various countries are encouraging for usage of EVs by offering various sops, the quicker

acceptance will depend upon the cost of vehicle, battery, battery life span, battery recharging points. A comprehensive review has been conducted on various batteries, their functioning, operating voltage, life span etc., Lithium-ion battery technology which is widely used in EVs, must be further improved to overcome the various drawbacks presently existing. This paper presents an overview on of various batteries technologies and various recharge techniques. This article will be useful for the researchers working in EV and serve as a handbook. EVs have a number of advantages over conventional ICE vehicles and have the potential to protect the environment and, hence the living beings for the future generations to come.

Conflict of Interest

The authors have no conflict of relevant interest to this article.

References

- [1] Tatiane Borchers, Dirk Wittowsky, Ricardo Augusto Souza Fernandes, “A Comprehensive Survey and Future Directions on Optimising Sustainable Urban Mobility”, *IEEE Access*, vol.12, pp. 63023 - 63048, April 2024.
- [2] Philipp Miklautsch, Manuel Woschank, “Decarbonizing Industrial Logistics”, vol.50, no.3, *IEEE Engineering Management Review*, pp. 149 – 156, Sept. 2022
- [3] Nnachi Gideon Ude, Richards Coneth Graham, Hamam Yskandar, “A Review of Current Status of Green Hydrogen Economy in Sub-Saharan Africa”, *IEEE Access*, vol. 12, pp. 149676 – 149699, Oct 2024
- [4] Indian National Air Quality Standards <https://cpcb.nic.in/displaypdf.php?id=bmF0aW9uYWwtYWlyLXF1YWxpdkHktaW5kZXgvRklOUwtUkVQT1JUX0FRSV8ucGRm>, Accessed 20 December 2024.
- [5] S. Paul Sathiyam, C. Benin Pratap, Albert Alexander Stonier, Geno Peter, Anli Sherine, K. Praghash, Vivekananda Ganji, “Comprehensive Assessment of Electric Vehicle Development, Deployment, and Policy Initiatives to Reduce GHG Emissions: Opportunities and Challenges”, *IEEE Access*, vol. 10, pp. 53614 - 53639, May 2022
- [6] Albert G. Boulanger, Andrew C. Chu, Watertown, MA, Suzanne Maxx, David L. Waltz, “Vehicle Electrification: Status and Issues”, *Proceedings of the IEEE*, vol. 99, noIssue: 6, pp. 1116-1138, June 2011
- [7] HAJI Zakaria, MOUNIR Hamid, EL MARJANI Abdellatif, AMARIR Imane, “Recent Advancements and Developments for Electric Vehicle Technology”, *International Conference of Computer Science and Renewable Energies (ICCSRE)*, DOI: 10.1109/ICCSRE.2019.8807726, July 2019
- [8] Mohammed Shurrab, Shakti Singh; Hadi Otrok, Rabeb Mizouni, Vinod Khadkikar, Hatem Zeineldin, “An Efficient Vehicle-to-Vehicle (V2V) Energy Sharing Framework”, *IEEE Internet of Things Journal*, vol. 9, no. 7, pp. 5315-5328, Sept 2021.
- [9] Shuohan Liu, Qiang Ni, Yue Cao, Jixing Cui, Daxin Tian, Yuan Zhuang, “A Reservation-Based Vehicle-to-Vehicle Charging Service Under Constraint of Parking Duration”, *IEEE Systems Journal*, vol. 17, no. 1, pp. 176 – 187, March 2023
- [10] Quarterly EV sales globally, <https://www.iea.org/data-and-statistics/charts/quarterly-electric-car-sales-by-region-2021-2024>
- [11] Ying Du, Junxiang Zhang, Yuntian Chen, Zhenjia Lin, Jinyue Yan, “Impact of Electric Vehicles Charging on the Resilience of Urban Power Systems”, *9th Asia Conference on Power and Electrical Engineering (ACPEE)*, DOI: 10.1109/ACPEE60788.2024.10532626, April 2024
- [12] Hui Li, Yongquan Chen, Keqiang Li, Chong Wang, Bokui Chen, “Transportation Internet: A Sustainable Solution for Intelligent Transportation Systems”, *IEEE Transactions on Intelligent Transportation Systems*, vol. 24, no. 12, pp. 15818 – 15829, Dec 2023
- [13] Salvatore Distefano, Andrea Di Giacomo, Manuel Mazzara, “Trustworthiness for Transportation Ecosystems: The Blockchain Vehicle Information System”, *IEEE Transactions on Intelligent Transportation Systems* vol. 22, no. 4, April 2021

- [14] Tulasi Krishna Gannavaram V, Rahul Bejgam, Saideep Sunkari, Sai Bhatt Keshipedi, Madhava Rao Rangaraju, Venu Dunde, "A Brief Study on Hybrid Electric Vehicles", Third International Conference on Inventive Research in Computing Applications (ICIRCA), DOI: 10.1109/ICIRCA51532.2021.9544968, Spet 2021
- [15] Vaishnavi Chandra Tella, Mohamad Alzayed, Hicham Chaoui, "A Comprehensive Review of Energy Management Strategies in Hybrid Electric Vehicles: Comparative Analysis and Challenges", IEEE Access, vol 12, pp. 181858 – 181878, Dec 2024
- [16] Syed Shehryar Ali Naqvi, Harun Jamil, Naeem Iqbal, Salabat Khan, Murad Ali Khan, Faiza Qayyum, Do-Hyeun Kim, "Evolving Electric Mobility Energy Efficiency: In-Depth Analysis of Integrated Electronic Control Unit Development in Electric Vehicles", IEEE Access, vol 12, pp. 15957 – 15983, 2024
- [17] Kexiang Wei, Hongguang Zhou, Xiong Shu, Songlin Xie, Konlayutt Punyawudho, "Research on Economic Benefits and Adaptability of Different ELV Powertrain Topologies", IEEE Access, vol. 12, pp. 92494 – 92505, Dec 2024
- [18] I. Aharon and A. Kuperman, "Topological overview of powertrains for battery-powered vehicles with range extenders," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 868–876, Mar. 2011
- [19] Jie Li, Yonggang Liu, Abbas Fotouhi, Xiangyu Wang, Zheng Chen, Yuanjian Zhang, Liang Li, "Cooperative Ecological Adaptive Cruise Control for Plug-In Hybrid Electric Vehicle Based on Approximate Dynamic Programming", IEEE Transactions on Vehicular Technology, vol. 72, no. 3, pp. 3132-3145, March 2023
- [20] Iqbal Husain, Burak Ozpineci, Md Sariful Islam, Emre Gurpinar, Gui-Jia Su, Wensong Yu, Shajjad Chowdhury, Lincoln Xue, Dhruvo Rahman, Raj Sahu, "Electric Drive Technology Trends, Challenges, and Opportunities for Future Electric Vehicles", Proceedings of the IEEE, vol. 109, no. 6, pp. 1039 – 1059, June 2021
- [21] Yalun Li, Minggao Ouyang, C. C. Chan, Xueliang Sun, Yonghua Song, Wei Cai, Yilin Xie, Yuqiong Mao, "Key Technologies and Prospects for Electric Vehicles Within Emerging Power Systems: Insights from Five Aspects", CSEE Journal of Power and Energy Systems, vol. 10, no. 2, pp. 439-447, March 2024
- [22] Hamza El Hafdaoui, Ahmed Khallaayoun, "Mathematical Modeling of Social Assessment for Alternative Fuel Vehicles", IEEE Access, vol 11, pp. 59108 – 59132, June 2023
- [23] Mohamed E. Elsayed, Osama M. Hebala, Hamdy A. Ashour, Mostafa S. Hamad, "A Comparative Study of Different Electric Vehicle Motor Drive Systems under Regenerative Braking Operations", 31st International Conference on Computer Theory and Applications (ICCTA), DOI: 10.1109/ICCTA54562.2021.9916634, Dec 2021
- [24] Nasser Hashemnia, Behzad Asaei, "Comparative study of using different electric motors in the electric vehicles", 18th International Conference on Electrical Machines, DOI: 10.1109/ICELMACH.2008.4800157, Sept 2008
- [25] A. Desrevelaux, A. Bouscayrol, R. Trigui, E. Castex, "Comparison of Different Models for Electric Vehicle with Heating System", IEEE Vehicle Power and Propulsion Conference (VPPC), DOI: 10.1109/VPPC.2017.8331041, Dec 2017
- [26] Lorenzo Berzi, Massimo Delogu, Marco Pierini, "A comparison of electric vehicles use-case scenarios: Application of a simulation framework to vehicle design optimization and energy consumption assessment", IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), DOI: 10.1109/EEEIC.2016.7555775, June 2016
- [27] Merve Yildirim, Mehmet Polat, Hasan Kürüm, "A survey on comparison of electric motor types and drives used for electric vehicles", 16th International Power Electronics and Motion Control Conference and Exposition, DOI: 10.1109/EPEPEMC.2014.6980715, Sept 2014
- [28] Valentin Totev, Vultchan Gueorgiev, "Batteries of Electric Vehicles", 13th Electrical Engineering Faculty Conference (BulEF), DOI: 10.1109/BulEF53491.2021.9690824, Feb 2022
- [29] Prashant Paudyal Sharma, Abhisek Karki, Ojaswi Lakhey, Bishal Silwal, "Comparative Analysis of Energy Consumption and Driving Range of Electric Vehicles", IEEE 4th International Conference on Sustainable Energy and Future Electric Transportation (SEFET), DOI: 10.1109/SEFET61574.2024.10718266, July 2024
- [30] Dhanasekar R, Vijayaraja L, Kaushik V N, Prasanth S, Poornesh C K, Ragnathan A, "An Overview of EV Batteries and Study Analysis on Charging Methodology", International Conference on Computer Communication and Informatics (ICCCI), DOI: 10.1109/ICCCI54379.2022.9740935, Jan 2022
- [31] Flah Aymen, Majed Alowaidi, Mohit Bajaj, Naveen Kumar Sharma, Shailendra Mishra, Sunil Kumar Sharma, "Electric Vehicle Model Based on Multiple Recharge System and a Particular Traction Motor Conception", IEEE Access, vol. 9, pp. 49308-49328, 2021

- [32] Omar N. Nezamuddin, Clayton L. Nicholas, Euzeli Cipriano dos Santos, "The Problem of Electric Vehicle Charging: State-of-the-Art and an Innovative Solution", *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no.5, pp. 4663 – 4673, May 2022
- [33] A K M Ahasan Habib; S. M. A. Motakabber, Muhammad I. Ibrahimy, "A Comparative Study of Electrochemical Battery for Electric Vehicles Applications", *IEEE International Conference on Power, Electrical, and Electronics and Industrial Applications (PEEIACON)*, DOI: 10.1109/PEEIACON48840.2019.9071955, Dec 2019
- [34] V. Vaideeswaran, S. Bhuvanesh, M. Devasena, "Battery Management Systems for Electric Vehicles using Lithium-Ion Batteries", *Innovations in Power and Advanced Computing Technologies (i-PACT)*, DOI: 10.1109/i-PACT44901.2019.8959965, March 2019
- [35] Qiyun Dang, Di Wu, Benoit Boulet, "Electric Vehicle Battery as Energy Storage Unit Consider Renewable Power Uncertainty", *IEEE Energy Conversion Congress and Exposition (ECCE)*, DOI: 10.1109/ECCE47101.2021.9595375, October 2021
- [36] Kai Zhang, Lulu Jiang, Zhongwei Deng, Yi Xie, Jonathan Couture, Xianke Lin, Jingjing Zhou, Xiaosong Hu, "An Early Soft Internal Short-Circuit Fault Diagnosis Method for Lithium-Ion Battery Packs in Electric Vehicles", *IEEE/ASME Transactions on Mechatronics*, vol. 28, no. 2, pp. 644 – 655, April 2023
- [37] Yuefeng Liu, Jiaqi Li, Gong Zhang, Bin Hua, Neal Xiong, "State of Charge Estimation of Lithium-Ion Batteries Based on Temporal Convolutional Network and Transfer Learning", *IEEE Access*, vol. 9, pp. 34177 – 34187, Feb 2021
- [38] Kaveh Sarrafan, Kashem M. Muttaqi, Danny Sutanto, "Real-Time Estimation of Model Parameters and State-of-Charge of Li-Ion Batteries in Electric Vehicles Using a New Mixed Estimation Model", *IEEE Transactions on Industry Applications*, vol. 56, no. 5, pp. 5417 – 5428, June 2020
- [39] Linhui Zhao, Pengliang Qin, "Accurate SOC Prediction and Monitoring of Each Cell in a Battery Pack Considering Various Influencing Factors", *IEEE Transactions on Industrial Electronics*, vol. 70, no. 1, pp. 1025 – 1035, Jan 2023
- [40] Philip Karl-Heinz Dost, Philipp Spichartz, Constantinos Sourkounis, "Charging Behavior of Users Utilizing Battery Electric Vehicles and Extended Range Electric Vehicles Within the Scope of a Field Test", *IEEE Transactions on Industry Applications*, vol. 54, no. 1, pp. 580 – 590, Feb 2018
- [41] Xiaohong Diao, Linru Jiang, Tian Gao, Liang Zhang, Junyu Zhang, Longfei Wang, Qizhi Wu, "Research on Electric Vehicle Charging Safety Warning Based on A-LSTM Algorithm", *IEEE Access*, vol. 11, pp. 55081 – 55093, May 2023
- [42] Sadeq Ali Qasem Mohammed, Jin-Woo Jung, "A Comprehensive State-of-the-Art Review of Wired/Wireless Charging Technologies for Battery Electric Vehicles: Classification/Common Topologies/Future Research Issues", *IEEE Access*, vol. 9, pp. 19572 – 19585, Jan 2021
- [43] Dong Sik Kim, Young Mo Chung, Beom Jin Chung, "On the Electric Energy Rate Plans in Charging Electric Vehicles", *IEEE Access*, vol. 12, pp. 97196 – 97206, July 2024
- [44] Husam Mahdi Al-Alwash, Eugen Borcoci, Marius-Constantin Vochin, Indika A. M. Balapuwaduge, Frank Y. Li, "Optimization Schedule Schemes for Charging Electric Vehicles: Overview, Challenges, and Solutions", *IEEE Access*, vol.12, pp. 32801 – 32818, Feb 2024
- [45] Wooyong Kim, Pyeong-Yeon Lee, Jonghoon Kim, Kyung-Soo Kim, "A Robust State of Charge Estimation Approach Based on Nonlinear Battery Cell Model for Lithium-Ion Batteries in Electric Vehicles", *IEEE Transactions on Vehicular Technology* vol. 70, no. 6, pp. 5638 – 5647, June 2021
- [46] O. A. Ruiz-Guzman, A. J. Ustariz-Farfan, E. A. Cano-Plata, "Modeling of electric vehicle chargers by its characterization in charging stages", *IEEE Workshop on Power Electronics and Power Quality Applications (PEPQA)*, DOI: 10.1109/PEPQA.2015.7168220, June 2015
- [47] Faezeh Kardan, Aditya Shekhar, Pavol Bauer, "Quantitative Comparison of the Empirical Lifetime Models for Power Electronic Devices in EV Fast Charging Application", *11th International Conference on Power Electronics and ECCE Asia (ICPE 2023 - ECCE Asia)*, August 2023
- [48] Sumitra K, Mary Synthia Regis Prabha D M, "A Comprehensive Study on the Communication Protocols for V2G Operations", *IEEE International Conference on Power Electronics, Smart Grid, and Renewable Energy (PESGRE)*, 10.1109/PESGRE58662.2023.10404921, Dec 2023
- [49] Mostafa M. Mahfouz, M. Reza Irvani, "Grid-Integration of Battery-Enabled DC Fast Charging Station for Electric Vehicles", *IEEE Transactions on Energy Conversion*, vol. 35, no. 11, pp. 375 – 385, June 2020