Journal of Informatics
Electrical and Electronics Engineering, 2024,
Vol. 05, Iss. 01, S. No. 105, pp. 1-6
ISSN (Online): 2582-7006

A Review on Fast Charging Methodologies of Electric Vehicles

Gaurangi Ajay Sawant[1], Tanvi Santosh Maske[2], Sayujyata Mahesh Khot[3], Kiran Namdev Jagtap[4], Nitin Baliram Sawant[5], Kalpesh Sunil Kamble[6]

[1,2,3,4,5]Dept. of Electrical Engineering, SSPM College Of Engineering, Kankavli, India
[6]Dept. of Mechanical Engineering, SSPM College Of Engineering, Kankavli, India
[1]gaurangi11sawant@gmail.com, [6]kalpeshkamblesspm@gmail.com

How to cite this paper: G. A. Sawant, T. S. Maske, S. M. Khot, K. N. Jagtap, N. B. Sawant, K. S. Kamble, "A Review on Fast Charging Methodologies of Electric Vehicles," *Journal of Informatics Electrical and Electronics Engineering* (JIEEE), Vol. 05, Iss. 01, S No. 105, pp. 1–6, 2024.

https://doi.org/10.54060/a2zjournals.jieee.105

Received: 04/12/2023
Accepted: 17/03/2024
Online First: 25/04/2024
Published: 25/04/2024

Abstract

The Li-Ion battery is charged using a constant voltage, constant current charging method. The solution, photovoltaic energy, is making its appearance in the EV charging infrastructure. By altering the transformer ratio, the inverter's voltage gain can be adjusted. Instantaneous thermal gradients are altered by fast charging. The grid and electricity quality may be impacted by EV charging. Creating a thorough and current overview of rapid charging methods for battery-electric vehicles (BEVs) is the aim of this study. The foundational ideas of single battery cell charging as well as existing and upcoming charging standards are covered in this paper. Globally, battery-powered electric vehicles are becoming more and more common. Numerous causes, such as the need to lessen noise and air pollution and our reliance on fossil fuels, are driving this trend. The primary disadvantage of modern electric vehicles is their short range and the length of time needed to charge their batteries. Significant progress has been achieved recently in using pulse charging, as opposed to continuous current and/or voltage supply, to shorten the charging time of batteries in electric cars through intensive research and development activities. The portion that needs to be concentrated on estimating the electrical properties of the vehicle's battery is crucial for learning about the potential driving range.

Keywords

Electric Vehicles, Li-Ion battery, Fast charging, Ultra-Fast Charging, Pulse charging

1. Introduction

The rising cost of oil and environmental concerns have led to a noticeable surge in interest in clean car technologies including fuel cell and electric vehicle (EV). The use of electric cars (EVs) in place of conventional vehicles (CVs) is growing in appeal. Electric batteries, which EVs run on, require recharging from the electrical grid. Electric vehicles (EVs) are undoubtedly a suitable link between the transportation and electricity industries. Electric vehicles (EVs) provide a sustainable way to lessen the environmental effect of mobility and reliance on conventional energy sources because of their low energy consumption and zero emissions. The desire for eco-friendly transportation is growing worldwide, which is why EV sales are rising quickly. Conventional gasoline-powered cars, particularly those found in cities, greatly increase air pollution mainly from CO2 emissions. Internal combustion engines (ICEs) are being effectively replaced by advanced electric vehicle (EV) technologies, such as Fuel-Cell Electric Vehicles (FCEV), Plug-in Hybrid Electric Vehicles (PHEV), and Battery Electric Vehicles (BEV). Developing battery technology to enable quick charging and increase battery life is the main focus of ongoing research. By 2020, approximately 5 million EVs are projected to be in use, reflecting a major rise in the mainstream acceptance of EVs [3].

The constant current (CC) and constant voltage (CV) approaches are typically used by battery chargers. Whereas CV delivers a mild temperature rise with a longer charging period, CC offers a higher temperature rise in a shorter amount of time. The maximum charging current (Imax) and voltage per cell (V/Icell) limitations set by battery manufacturers prevent the constant current (CC) and constant voltage (CV) methods from meeting the minimal temperature rise and 30-minute charging time expectations of electric vehicle (EV) users. In conclusion, despite falling costs and significant performance improvements, barriers like lithium-ion battery degradation during rest and cycling, charging rate limitations resulting from electrochemical processes, and relatively low energy density (in comparison to petroleum) still prevent EVs from being widely adopted [4].

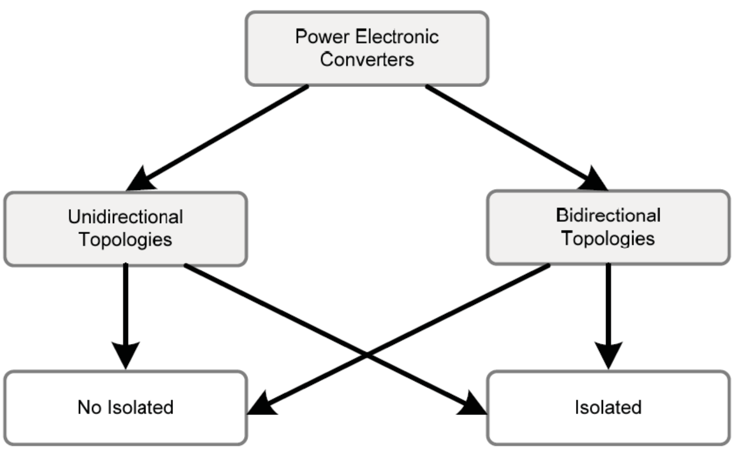

Figure 1. The primary types of ac-dc power converter topologies utilized in EV battery charging systems

2. Background

It is impossible to ignore the effects of the growing number of EVs since Similar to how electric vehicle (EV) battery charging systems were not initially intended to be handled, the current electrical power networks were not equipped to handle this new kind of load. The task at hand involves reconstructing the electrical power grids in the most expedient, environmentally sustainable, and "smarter" manner feasible. Electric vehicles (EVs) are a special kind of load that offer fresh possibilities for action as well as new challenges. The potential for numerous cars to be charged at once presents difficulties as it could overload the electrical infrastructure. These issues are further compounded by battery charging systems' non-sinusoidal current usage. Among the opportunities is the fact that, if they cooperate with These parked cars have a great deal of potential to control the grid's consumption profile by using the grid to store and distribute energy from their batteries. They can provide voltage and frequency stability on the grid and mitigate the intermittent nature of renewable energy sources. As previously indicated, certain cars permit their batteries to be charged using off-board systems, such as those found at public charging stations, but the majority of cars have on-board battery charging systems. To extend the life of the charging system, which functions as an AC-DC power circuit, adherence to the nominal characteristics of the vehicle's batteries is recommended [1, 6].

Today's EVs use a variety of Li-ion battery derivatives, several of which are still in development. In an effort to maximise the battery's longevity, safety, and performance, researchers might choose the electrolyte, positive, and negative electrodes. Fig. 1 depicts the normal charging procedure for a single lithium battery cell. There are two phases in the procedure. First, the cell passes through a continuous current (CC) stage, in which the nominal cell voltage, or 4.2 V, is shown, while the voltage rises from 3.0 V, which denotes a depletion condition. At this moment, the cell voltage is regulated to stay constant (at the CV stage) until the current approaches zero.[2] Increasing the current in the CC stage can save the time it takes to charge the battery, but high currents might damage the cell permanently or shorten its lifespan. A basic analysis using a crude battery model similar to the one in Fig. 2 demonstrates that applying a larger current causes higher loss because of the internal resistance of the battery cell. As a result, proper thermal control is necessary for fast charging in order to keep the battery's temperature within a safe range [7].

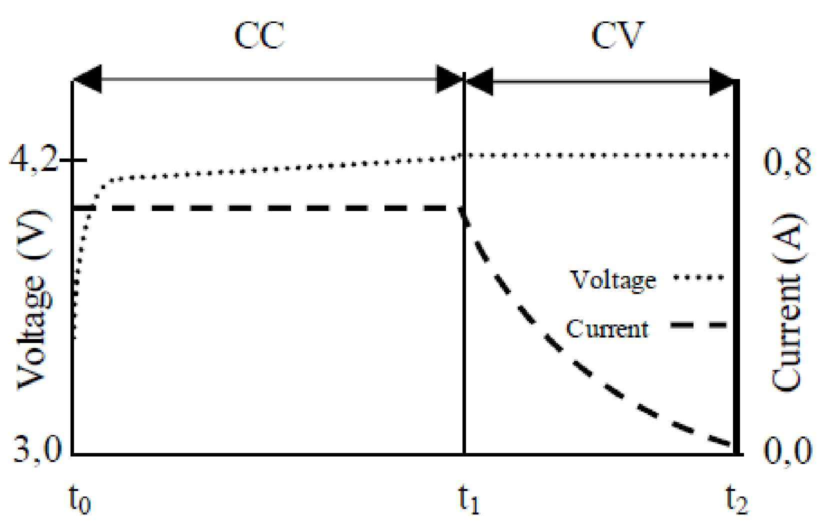

Figure 2. Single lithium battery cell charging process

3. Battery Charging Methodologies

When recharging EV batteries, many physical implementations and techniques are used. The battery charging strategy deals with the kinds and amounts of currents and voltages used during charging, whereas the physical configuration of the battery charging infrastructure deals with how energy is physically delivered to the car [8, 15].

3.1. Constant Voltage

As the battery gets closer to full charge, a constant voltage charge progressively reduces the charging current while maintaining the charging voltage at the ideal level appropriate for that specific kind of battery. When utilizing lower voltages, this works well because temperature is typically not a problem, but long charge times are a worry [16], 18].

3.2. Constant Current

As the name suggests, this charging technique applies a steady current to boost the battery voltage to its maximum charge level. Even when applied within the stated current limit, supplying a steady current to the battery can quickly lead to overheating and damage, reducing the battery's lifespan [14,16].

3.3. Constant Current-Constant Voltage (CC-CV)

Constant current-constant voltage charging, often known as "Voltage Controlled Charging," is a popular battery charging technology. This method involves the charger running continuously until the battery reaches a certain voltage. At that point, the voltage is held constant and the current keeps decreasing until the battery is fully charged. The conventional approach to battery charging, shown in Figure 4, has limitations when it comes to fast-charging applications because cell polarization becomes a problem. As expected, the CC-CV technique has been further improved to incorporate numerous phases of constant current, which accelerates the rate at which batteries charge [15-17].

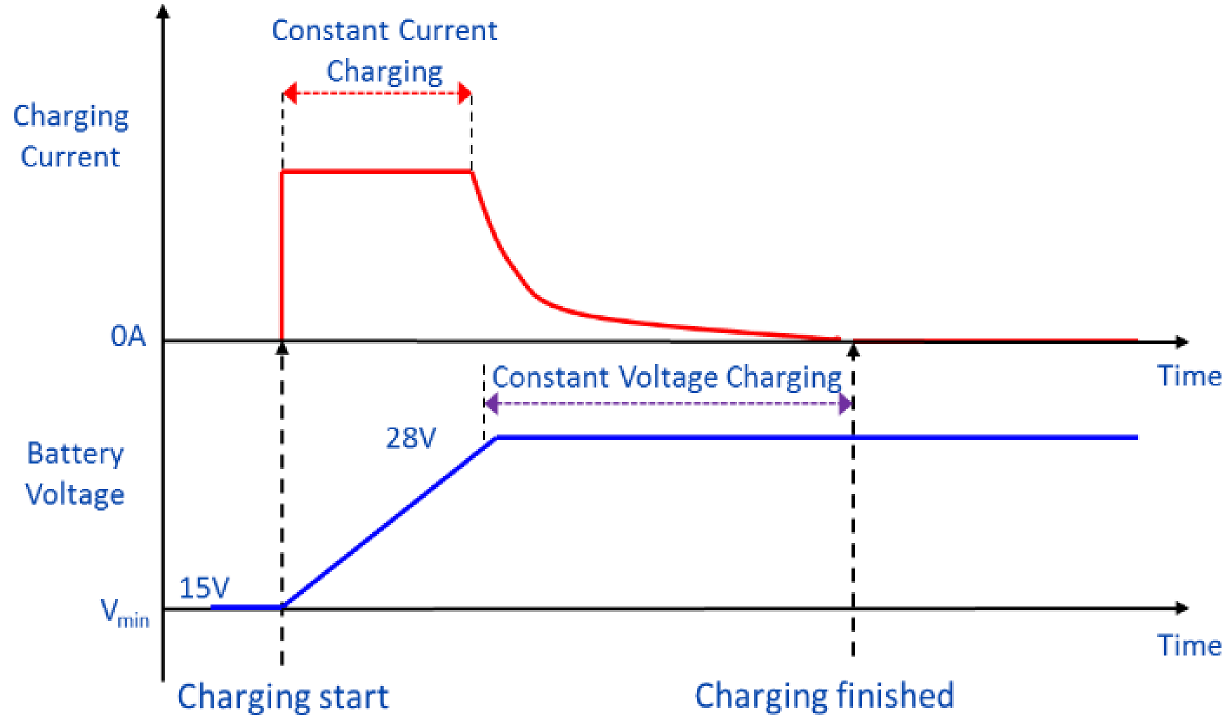

Figure 3. Constant current-constant voltage battery charging

3.4. Pulse charging

With pulse charging, the battery receives current pulses that are designed to maximize the charging duration while taking polarisation, battery temperature, SoC, and changeable battery impedance into account. The ions are able to permeate through the electrode materials during the rest interval of each pulse cycle, improving the charging process' efficiency [13, 15].

3.5. Negative Pulse Charging

Negative pulse charging strategies are used to apply modest discharges to the battery during the pulse charging rest interval. These methods, which were originally created to improve the performance of lead-acid battery charging converters, have now been modified for use with lithium-ion batteries. The negative impulse serves to minimize the cell's temperature rise and reduces tensions inside the cell. Because the negative pulse draws very little energy, circuit topologies that can recover the energy from the battery have been developed. High currents may be continuously delivered to the battery, allowing for a faster charging rate and shorter charging time, by periodically depolarizing the cell. This technique can greatly extend the battery's life and aid in its internal chemical reactions [18].

4. Ultra fast charging and future scope

A number of new technologies have the potential to make owning and operating emission-free cars easier. The days of worrying about "range anxiety" and "long charging times" are quickly coming to an end with wireless power available and battery packs that can last up to 500 miles between charges, which just take a few seconds.

We are about to witness a revolution in batteries. Electric vehicle manufacturers are aware that Americans want more range and faster charging times in order for EVs to be in every garage. They know about the restrictions on lithium-ion batteries, which are used in modern electric cars. A vulnerability affecting battery packs has been found to be impeding the development of operating systems and computer circuits that use less energy. Using carbon fiber as the negative electrode and lithium iron phosphate as the positive electrode is the suggested solution. This would provide batteries with remarkable stiffness and rigidity that may be used as structural components [8, 9, 17].

A business called Graphenano is working on a graphene battery that will reportedly be able to travel 500 miles before needing to be recharged in a matter of minutes. These batteries will charge and discharge 33 times quicker than lithium-ion batteries, according to the maker [9].

Recently, a single battery charge allowed an experimental car to go 1,100 kilometers. Aluminium-air battery technology, which replenishes the cathode of an electric vehicle using ambient air oxygen, made this accomplishment possible. By using this technique, the batteries become much lighter than lithium-ion batteries that are loaded with liquid, which increases the vehicle's range [4, 17, 18].

5. Conclusions

This paper reviewed current fast charging technologies, discussed problems with fast charging, such as restrictions and effects on battery systems' ability to handle heat, offered remedies, and suggested new direction for future research. The world will not be able to survive on petroleum-based transportation in the coming decades, so cutting-edge technologies are required to transition to electric transportation that is sustainable. One of the main issues with EVs is their slow charging times. To be widely accepted by consumers, the time needed for recharging must be comparable to the amount of time needed to fill up the gas tank of an ICEV. In order to promote a greater uptake of electric cars and facilitate the shift to a more sustainable energy future, improvements and standardizations are essential. Future developments in electric car charging will primarily focus on contactless charging, rapid charging, using sustainable or renewable energy sources, and investigating vehicle-to-home or grid-to-vehicle capabilities. When commercializing electric vehicles, rapid pulse charging is essential to reducing charging times to a manageable level. A fast-charged battery can overheat, weaken performance, and cause damage to the battery; deep discharge, on the other hand, is the root cause of permanent damage. The Battery Management System (BMS) helps to improve battery life, lower damage rate, and optimize capacity, efficacy, durability, and reliability in battery stacks.

Reference

[1.] C. C. Tsai, W. M. Lin, C. H. L. M. S. Wu, "Designing a Fast Battery Charger for Electric Bikes," *International Conference on System Science and Engineering, IEEE, Taipei*, 2010.

[2.] Z. Zhang, H. Xu, L. Shi, D. Li, Y. Han "Application Research of an Electric Vehicle DC Fast Charger in Smart Grids," *2012 IEEE 6th International Conference on Information and Automation for Sustainability, Beijing*, 27-29 September 2012.

[3.] Z. Mohammad Rejwan Uddin, S. Tasneem, and M. Khosru, "A High Capacity Synchro-nous Buck Converter for Highly Efficient and Lightweight Charger of Electric Easy Bikes," *in International Conference on Electrical, Bangladesh,* 2017.

[4.] S. Liu, B. Ge, and X. Jiang, Haitham Abu-Rub, Fang Z. Peng, "A Novel Indirect Quasi-Z-Source Matrix Converter Applied to Induction Motor Drives," *in Energy Conversion Congress and Exposition. Denver, CO, USA: IEEE*, 2013.

[5.] P. Yam, F. Siwakoti, P. C. Blaabjerg, and G. E. Loh, "A High Voltage Gain Quasi Z-Source Iso-lated DC/DC Converter," *in IEEE International Symposium on Circuits and Systems (ISCAS), Melbourne, VIC, Australia*, pp. 1–05, 2014,

[6.] P. Yam, Student "Improved Modulation Technique for Voltage Fed Quasi-Z Source DC/DC Converter." *Fort Worth, TX, USA,* 2014.

[7.] Y. R. Kafle, S. U. Hasan, M. Kashif, J. Hossain, and G. E. Town, "A new PWM Shoot-through control for voltage-fed quasi-z-source DC/DC converters," *in 2017 IEEE International Telecommunications Energy Conference (INTELEC)*, 2017.

[8.] J. Liu, J. Wu, J. Qiu, And J. Zeng, "Switched Z- Source/Quasi-Z-Source DC-DC Converters With Reduced Passive Components for Photovoltaic Systems", *IEEE Access*, vol. 7, pp. 40893 – 40903, 26 March2019.

[9.] L. Yang Dongyuan Qiu and B. Z. G. Zhang, "Wenxun Xiao "A quasi-Z-source DC-DC converter," *IEEE Energy Conversion Congress and Exposition*, pp. 14–18, 2014.

[10.] A. Hadi, H. Hussain, M. Mansor, and I. Said, "Fast charger for Li-ion batteries based on battery temperature," in *3rd IET International Conference on Clean Energy and Technology (CEAT) 2014*, 2014.

[11.] O. Ibrahim, N. Z. Yahaya, N. Saad, and K. Y. Ahmed, "Design and simulation of phase-shifted full bridge converter for hybrid energy systems," in *2016 6th International Conference on Intelligent and Advanced Systems (ICIAS)*, 2016.

[12.] J. Lu *et al.*, "A Modular Designed Three-phase High-efficiency High-power-density EV Battery Charger Using Du-al/Triple-Phase-Shift Control," *IEEE Transactions on Power Electronics*, vol. 33, no. 9, pp. 8091–8100, 2018.

[13.] Y. Sun and B. Jiao, "Design of a Soft-Switched Phase-Shift Full Bridge Converter"," in *3rd International Conference on Systems and Informatics (ICSAI)*, Shanghai, China, 2016, pp. 230–234.

[14.] C. Pu, Z. Hao, C. Shao, and X. Ren, "Two- stage Interleaving DC/DC Topology Based on Phase-shift Full bridge Converter," in *IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS- ITEC)*, Nottingham, UK, pp. 7–09, 2018.

[15.] R. Amol, H. Suhas, and M. S. Mhabadi, "Design and Implementation of Quasi Z-source Converter Based Battery Charger for Electric Vehicles," in *2023 IEEE 8th International Conference for Convergence in Technology (I2CT)*, India, pp. 7–9, 2023.

[16.] K. S. Somnatha, M. K. Gupatab "Review Paper on Electric Vehicle Charging and Battery Management System", *ICCIP*-2019.

[17.] R. Collin, Y. Miao, A. Yokochi, P. Enjeti, A. V. Jouanne, "Advanced Electric Vehicle Fast-Charging Technologies", https://www.researchgate.net/publication/333115032.

[18.] H. Tu, H. Feng, S. Srdic, and S. Lu ,"Extreme Fast Charging of Electric Vehicles: A Technology Overview", *IEEE Digi Library.*