International Journal of Scientific Engineering and Technology
Volume No. 12, Special Issue No. 1

ISSN : 2277-1581
29 Dec. 2023

Review on Bidirectional DC-DC Converter for Electric Vehicles Application

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Abstract: The rapid advancement in power electronics converter technology and fast speed controller technology has increased the popularity of power electronics based equipment's like battery chargers, inverters, SMPS supply for industrial and commercial application. The power electronics devices are used as a switches for efficient control of power, in various application like electrical vehicle battery charging, power flow in both the direction in grid to vehicle, and vehicle to grid using various types of DC-DC converters, non-isolated as well as isolated converter. The non- isolated bidirectional DC-DC converter has a found unique solution for small size, lesser weight chargers, six types of non-isolated converters are available in the literature, bidirectional buck-boost converter, cascaded bidirectional buck- boost converter, bidirectional SEPIC-ZETA DC-DC converter, switched capacitor bidirectional dc to dc Converter, and Interleaved Non-isolated Bidirectional dc to dc converter. The bidirectional buck-boost converter is mostly used for electrical vehicle charging application. In isolated dc-dc converter topologies full bridge converter is more popular because of its easy control and higher efficiency, in this converter series resonant tank is plays a significant role to achieve zero voltage switching for both side of operation in charging as well as discharging is cost effective solution. A survey of various bidirectional DC-DC converters for electrical vehicle charging application.

Keywords: Electric Vehicles (EV), DC-DC Converter, Bi-directional.

1. Introduction:

On recent years due to global warming CO2 emissions in increased rapidly and air pollution also increased due to various sources like conventional IC(internal combustion) engine-based vehicles, diesel engine-based railway locomotive, heavy vehicles, airplanes, etc. nearly 25% of greenhouse gases are contributed by conventional transportation. Crude oil demand increases day by day because of population growth. In India country population rate is too high and increased hence the consumption of crude oil based vehicle increased.

Present-day air pollution in India is very severe health issue [1]. In the world's 30 most contaminated cities list 2019, 21 were in India. As per a study centered on 2016 statistics, at least 140 million persons in India respire air that is ten times or more over the WHO safe limit. Fifty-one percentage of pollution is caused by industrial pollution, twenty-seven percentages by vehicles, seventeen percentages by harvest burning, and five percentages by fireworks shown in Figure.1.

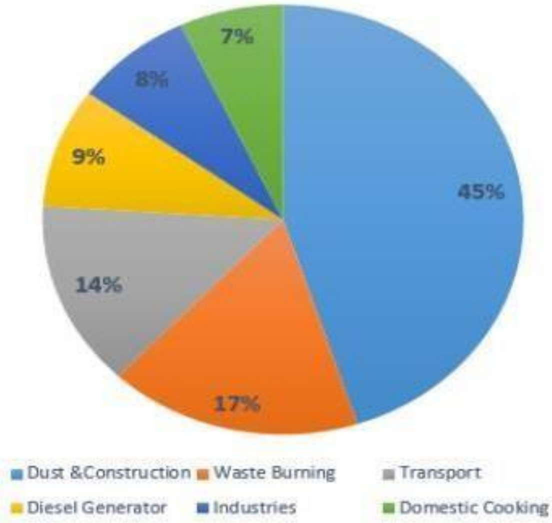
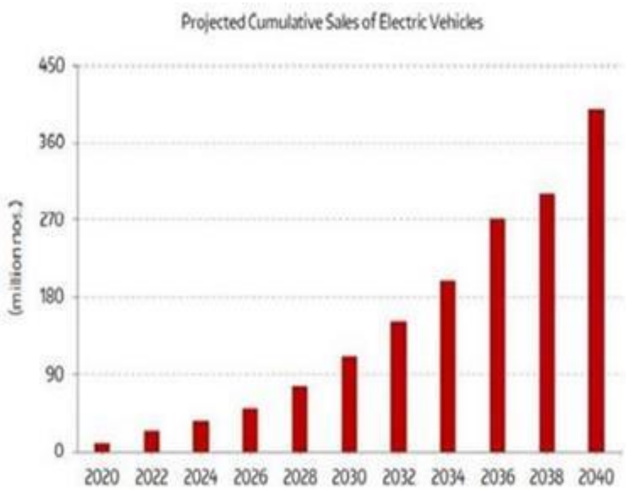


Figure 1: Sources of air pollution in India

For reduction of air pollution and reduce the import of crude oil from other countries India start an initiative to use renewable energy and alternate sources of conventional public transport based on petrol and diesel [2]. Indian government starts various initiatives like the uses of electric mobility, increasing electric generation based on renewable energy, etc. India includes uses of an electrical vehicle in their transport policies the response have diverse permitting to their stage of financial growth, energy reserve aids, technical capabilities, and political arrangement of responses to environmental deviation. The sales of electrical vehicle in the Indian market is increased by 10X in the next two decade shown in Figure. 2.



Figyew 2: The sales of electrical vehicles for the Indian market in the next two decades.

These circumstances have prompted India to adopt an electric vehicle policy to systematically ensure that India's electric vehicle plan is kept in step by the international scale because big markets due to having taken important steps about the electrification of vehicles. India's development outlook produces the possibility to develop a control position in electric vehicles in specific areas. In this perception, the strategy will promote a way that initiates with the particular features and initiatives of the Indian automotive industry and moves around worldwide importance as well as applications [3]. The main goals of the electric vehicle procedure are:

1. Reduction crude oil consumption in transport.
2. Ease consumer acceptance of electric and clean energy vehicles.
3. Stimulating state-of-the-art techniques in India over adoption, and R&D.
4. Enhance the revenues of transport utilized by ordinary people for individual and cargo transport.
5. Decrease greenhouse gasses in the urban area.
6. Generate electrical vehicle production capability that is of reliable and effective.
7. Increase the job demand in solar energy field.

2. Literature Review

Vikram Singh et al. [1], sustainable power based battery charging frameworks for Electric Vehicles (EV) have seen flood in car research in most recent couple of years. In this study, EVs that are powered by solar PV are thoroughly examined. Zero emissions, load leveling, excellent transient functioning, and the capacity to recover energy while braking are among the many advantages of using batteries to store energy in ground vehicles. To connect PV to the dc-link of the battery, a bidirectional DC-DC converter is required to meet these requirements. A PV-powered electric vehicle must be capable of two modes of operation: charging and releasing. Greatest Power Point Following (MPPT) method is used in this review to gather most power by sun based PV. Additionally, the proposed closed-loop control circuit for a DC-DC converter with bidirectional output is needed. The effectiveness of the system is verified through MATLAB simulations.

Suraj et al. [2], the petroleum product consumption and flood in power request have prepared to extreme entrance of environmentally friendly power sources, particularly Sun based. The development in photovoltaic framework and its pinnacle power age from 11 am to 3 pm, when the power request is low, requires energy capacity framework (ESS) for productive use of photovoltaic power age. In this paper, Photovoltaic Energy Stockpiling Framework in the Indian situation is created by thinking about the charging of Electric Vehicle (EV) Battery and Assistant Battery (Stomach muscle) during the pinnacle power age of sunlight based photovoltaic (SPV) framework connecting with power electronic
converters. In this proposed work, the Auxiliary Existence of High-Limit EV battery is used as Stomach muscle. The bidirectional DC-DC converter based on switched capacitors (SC) is used to connect the DC link voltage of the SPV to the EV and AB charging systems. With the SPV system's hardware setup, a SC-based power converter, and 18650 3000mAh Li-Ion cells used as EV and AB, the proposed methodology is confirmed.

Abdalrahman Elshora et al. [3], recently, it was reported that the transportation sector in Canada was the second- largest source of greenhouse gases. Accordingly, scientists have been keen on creating charging control frameworks for electrical vehicles. The super two difficulties are the size of the energy stockpiling and the charging time. Investigates demonstrate that crossover energy capacity can increment energy thickness and dependability other than lessening the all-out cost of energy. However, it is difficult to control multiple energy sources. This paper presents a bidirectional DC converter that can oversee half breed energy capacity made out of different wellsprings of energy. By adding a few components, it makes modular expansion of input energy sources possible. It empowers power stream in every conceivable bearing. Using Matlab Simulink, the proposed converter has been simulated and successfully validated in the majority of charging and discharging operating scenarios.

Y. Q. Wang et al. [4], a novel switched-capacitor- based T-type multilevel inverter (MLI) is proposed in this paper. The proposed inverter not just accomplishes that the greatest voltage stress of the switches is not exactly the information voltage yet in addition has a voltage support capacity, which makes it reasonable in high voltage applications. It is important to point out that the proposed inverter has two topology extension schemes that help it get a higher voltage gain and output level. A seven-level inverter can be constructed with just two capacitors thanks to the advantages of low voltage stress and low power consumption. In addition, the capability of capacitor voltage self-balancing can reduce the complexity of the control and circuit. The inverter's capacitor topology, operating principle, modulation strategy, and analysis are presented. The superiorities of the proposed inverter are explored by contrasting and as of late proposed half breed MLIs and exchanged capacitor MLIs. At long last, a seven-level model is developed to approve the rightness of the hypothetical investigation and the practicality and viability of the proposed inverter.

Vivek Kumar Singh et al. [5], the load is supplied with single-phase ac in this system. The non-direct burden creates music in the info signal. Improved stage locked circle (EPLL) gives sinusoidal current from contorted waveform. The charger is associated through this stock for charging the EV battery. The charger has two phase (a) 1-Øbidirectional AC-DC converter (b) three-level DC buck help converter. The three-level buck boost converter receives DC-link voltage from the AC-DC converter. The electric vehicles battery is charged in buck mode for framework to-vehicle application and release in support mode for vehicle-to-network application. This joining of bidirectional ac-dc converter with the proposed three-level bidirectional dc converter give way to the progression of capacity to decides the condition of charge (SOC) of EV batteries for charging mode

S. Athikkal et al. [6], non-disconnected DC converters with multi input highlight are exceptionally well known in the space of crossover energy combination since they are reduced, cost proficient contrasted with the segregated geographies. A Double Information Half and half move forward DC converter (DIHDC) with a reduced construction is presented in this paper. The switched inductor method is what drives DIHDC. In the initial working modes (also known as the switch on condition), DIHDC has two equal-valued inductors that are energized parallelly. In the final working modes (also known as the switch off condition), the stored energy is dissipated in series. Likewise, the proposed converter can be stretched out up to different contributions with slight alterations in the construction. The new converter may have advantages such as a straightforward and compact design, relatively higher efficiency, and a favorable voltage conversion ratio. Examination of DIHDC in consistent state condition is made sense of extravagantly and the reproduction results are introduced. A research facility scale converter model has been created to affirm the proficient activity of DIHDC in practical circumstances.

Y. Jeong et al. [7], this paper proposes a novel multi-input and singleoutput DC/DC converter for little automated flying vehicle applications, e.g., multi- rotor drones. A blend of force sources, including a power device, battery, and a super-capacitor, is considered to expand the flight season of such robots. For those different sources, the proposed DC/DC power converter comprises of two utilitarian parts, which are the charging and releasing activity for the battery and super-capacitor and the guideline of the result voltage. Additionally, two operating modes based on the primary power sources are discussed. Hence, the proposed converter can accomplish high power thickness and minimal expense on the grounds that the proposed converter can have little counts of parts with similar elements of the ordinary converter. A 400 W prototype (14.8 V/27.03 A) proved the proposed converter's viability, and experimental results demonstrated the converter's efficacy for small unmanned aerial vehicle applications and validated the theoretical analysis.

Y. Q. Wang et al. [8], the large number of devices and complicated expansion of conventional multilevel inverters cause issues. This paper proposes a particular extended staggered inverter, which can really work on the extension and lessen the quantity of gadgets. The voltage-dividing capacitors can be guaranteed to be voltage-balanced by the proposed inverter. The inverter is able to achieve high output voltage levels and voltage gain thanks to the cascading of the T-type switched capacitor module and the step-by-step charging method of the switched capacitors. Also, the reversal can be accomplished without the H-span, which extraordinarily lessens the absolute standing voltage of the switches. With only ten switches, the proposed topology's nine-level inverter achieves a voltage gain that is two times greater. Experiments and theoretical analysis confirmed the preceding advantages. In photovoltaic power generation at medium and low voltages, the proposed inverter has promising potential applications.

S. Habib et al. [9], zapping the vehicle area requires additional opportunities for power hardware converters to achieve dependable and effective charging answers for electric vehicles (EVs). With the consistent advancement in power gadgets converters, the craving to diminish fuel utilization and to expand the battery limit with regards to more electric, reach is feasible for EVs sooner rather than later. The fundamental point of interaction between the power organization and EV battery framework is a power hardware converter, in this manner, there is an extensive need of new power converters with minimal expense and high dependability for the development charging system of EVs. The fast development in power converter geographies acquires significant open doors EV charging process. In light of this, the purpose of this paper is to suggest additional enhancements to EV charging systems by examining the significant aspects, current progress, and challenges of a number of power converters. Specifically, a broad examination of front- end as well as back-end converter setups is introduced. In addition, the properties of resonant converter topologies and other DCDC converters are compared and contrasted in great detail. Moreover, confined, and non-disengaged geographies with delicate exchanging procedures are grouped and thoroughly examined with a view to their separate issues and advantages. For researchers looking into power converter topologies for EV charging solutions, it is anticipated that this paper will be a useful addition and a worthy source of information.

3, Dc-Dc Converters:

DC-DC converter are classified accordingly their galvanic isolation in two categories non-isolated DC- DC converter and isolated DC-DC converter. Figure. 3 shows the classification of different types of DC-DC converters, which are linear mode power supplies, hard and soft-switching DC-DC converters. The advantages of regulators (series and parallel) using linear power supplies are low cost, simple design, and low noise

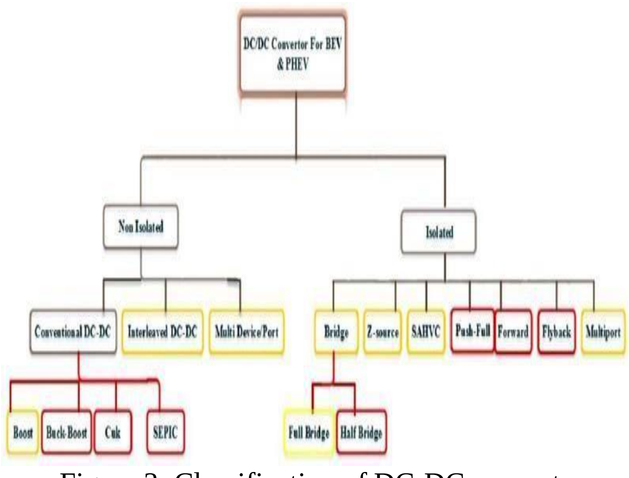


Figure 3: Classification of DC-DC converters

However, the linear power supplies are not suitable for high switching frequency and high power uses as well. The power supplies based on hard-switching (no isolated and isolated) and soft-switching DC-DC converters can withstand high power and high switching frequencies. The major drawbacks of the hard switching converters are poor efficiency and increased turn-on/off switching losses concerning the switching frequency, the operating input, and output power levels. These problems can overcome by soft- switching DC-DC converters

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ISSN : 2277-1581
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Non-isolated DC-DC Converters

The BDCs without a transformer [6-12] can be operated either across boost or buck mode. The converter topology through high-frequency transformer is preferable to deliver galvanic isolation among the source as well as the load. To reduce the overall cost, volume, and improved efficiency, the non-isolated BDCs are alternate solutions to the industry. Non-isolated BDCs can be operated at high power applications; however, the size and weights are lesser than the isolated converters. The non-isolated BDCs are more economical than the isolated BDCs. To achieve the dual characteristics of a converter as bidirectional, a parallel connection of the boost and buck converters has been made. The converter is applied to gain the higher output voltage from the lower input voltage (from the battery) and provides the desired input voltage to the inverter. While the converter is operated in buck mode, the regenerative braking of the motor is obtained. This mode of operations may also provide the path for current in braking.

Isolated Bidirectional Converters

It is a type of bidirectional DC-DC converter, where, a high-frequency transformer (HFT) plays an important role by providing the isolation between the input and load. The HFT can affect the overall cost and creates additional losses. There are many such isolated converter topologies are reported in the last decade [12-19] as half-bridge (HB), full- bridge (FB), current fed HB, current fed FB, and Push-Pull HBs, etc. The major advantages of these converter topologies are given as follows:

- Galvanic isolation
- Number of component is reduced because of the minimum number of active switching devices In the FB and HB converter topologies, the transfer of the energy in a bidirectional manner is achieved by utilizing the leakage inductance of HFT as part of it

4. Energy Storage System For Electric Vehicle

Various types of battery chemistry are available for electric vehicle applications. Li-ion battery is more suitable for EVs due to its battery property comparing to other battery options for an electric vehicle. Figure 1 presents a Battery power comparative market price comparison of multiple electric vehicles [11].

Battery energy storage topologies

Battery-based energy storage technology is divided into three topologies as with hybrid energy storage electric vehicles called as HEVs, external plug-based plug hybrid energy storage electric vehicles called PHEVs, and battery-based energy storage only called vehicles as EVs.

In Hybrid Electric Vehicles main power source is an IC engine combined with electric powered motors that use to store the energy in batteries. Gasoline- powered IC engine is the primary and batteries are the auxiliary parts for the energy source in HEV. Battery energy storage capacity is 1-3 kWh, by using this capacity vehicle can drive approximately 10 kilometers.

Plug-in hybrid electric vehicles (PHEVs) use the battery and another fuel gauge for energy storage. batteries are used to power an electric motor and use another fuel, which is used to powered propulsion source. PHEV uses grid electricity to charge the battery which reduces the cost of the fuel. PHEVs have large battery packs compared to hybrid electric vehicles. This helps to travel more distances using only energy (about 30 to 60-plus kilometers in existing models), commonly referred to as the vehicle's "battery-powered range"[12].

Figure. 4: Comparative assessment of different market costs for electric vehicles

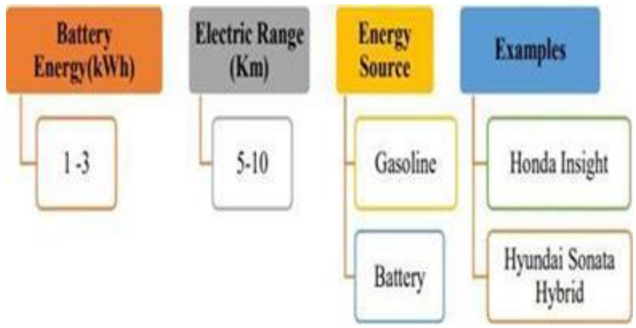

Figure. 5: Hybrid Electric Vehicle specifications

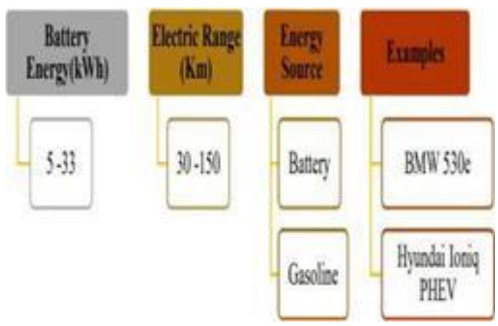

Figure. 6: Plug-In Hybrid Electric Vehicle specifications

Vehicles including only battery-based energy storage are called BEV. These types of electric vehicles (EVs) use the battery bank to store the electrical energy that powers the motor. The battery bank is charged by using an external plug that extracts the energy from a charging station. Charging stations are power by electricity, BEV is considered as zero carbon emission vehicles because they do not produce direct exhaust or emissions comparatively other conventional vehicles [14]. For the electric cars, the energy storage is up to 100 kWh and the electric range is approximately 500 kilometers targets have been explored

5, Conclusions:

The isolated series resonant full-bridge bidirectional dc-dc converter for electrical vehicle application besides with working principle and features are presented. As the series resonant-based fullbridge bidirectional converter is a two-stage conversion device for bidirectional operation, it provides tremendous interest in the electric vehicle charging industry as well as domestic DC microgrids where fast charging is needed that we are achieving through high switching frequency. The series resonant-based full-bridge converter has several advantages like simple pulse width modulation control is used to control the transfer power, and zero voltage switching for all the switches within vast voltage range is switching frequency fixed at the resonant frequency of the series resonant tank

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