Electric Vehicle Motor, Converter, Controller and Charging Station with Challenges and Configurations: Review

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Abstract- Electric vehicles (EVs) are an emerging technology that enhances the ecology and environmental respect around the world through the automobile industry. The impact of electric vehicles mainly depends upon the efficient output of batteries and power converters. Converters and controllers used in the Electric vehicle have many drawbacks such as large switching loss, reduced dynamic response, increased current stress, and a larger number of components. The effectiveness of controllers, converters, and motors should be necessary to achieve reliable output power from the storage systems. Therefore it is necessary to choose the appropriate converter, controller, and motor to get efficient output. This review paper explores different types of converters, power controllers, motors, and charging stations with its advantage and disadvantage. A comparison was made on various types of Electric vehicles, power converters, controllers, charging stations, and motor with their commercial demand. Finally, this review article explores the challenges and gives suggestions for future electric vehicle development and application.

Keywords Electric Vehicle, DC-DC Converter, Controllers, Modulation Techniques, Solar Charging Station, EV Motors.

1. Introduction

Electric vehicles (EVs) are recognized as an efficient source in the automotive industry compare to fossil-fueled source vehicles since they utilize pollution-free energy resources and can attain efficient output [1]. The major concerns about environmental issues like pollution, global warming, and power issues lead to the deficiency in fossil fuels which increases in fuel price, so automobile manufacturers deviated their attention against clean vehicle automation. Now- a -days due to the improvement in battery technologies, internal combustion vehicles are replaced as Electric vehicles mainly in Power Electronics Interfaces (PEIs) and control scenarios. An electric vehicle mainly contains the following components: a motor controller, a plug-in charger, traction battery, a battery management system, and an electric motor that can be operated independently from the vehicle [2].

The various components of Electric vehicles reviewed are illustrated in figure 1. A European union researched greenhouse gases emitted by combustion vehicles. The research results nearly combustion vehicle emits nearly 70% of gas while other transport zones are nearly 27% of toxin greenhouse gas [3].EVs always have great attention over the world because of their high efficiency, nil carbon emissions, less noise, enriched performance, and reduced weight [4]. China has provided economical subsidies for reliable powered EVs. Likewise, India also aiming to achieve its desire in EV manufacturing by 2030. The major challenges faced by EVs are driving range, battery cost, and the time is taken to recharge[5,6]. By taking that into consideration, the factor affecting converters, controllers, motors are considered in the EV drive train.

Efficient Electric drive vehicles have greater attention due to their low greenhouse gas discharge, efficient power system operation with lesser operating cost. Electric vehicles can be classified into plug-in type (PHEVs), Hybrid Electric Vehicles (HEVs), and General electric vehicles (EVs) [7].

EVs are formed by various types of Energy Storage System (ESS) which is connected with different types of power converters [8, 9]. Generally, through a grid or charging station, the ESSs are charged by taking current and voltage from AC-DC converters [10]. Hence, DC-DC converters are mainly used for converting an unregulated power flow into the regulated one [11, 12]. In EV applications a hybrid ESS focuses mainly on an energy management strategy, sizing, and DC/DC converter configuration. Besides that, DC-DC converters focus on lightly damped dynamics and non-linear behavior due to their switching actions [13, 14]. The operation and design of converters used in EVs were discussed along with the different types of DC-DC converters, converter topologies, and their interpretations. The difficulties in implementing optimization techniques and controllers to the converters are not addressed [15-16].

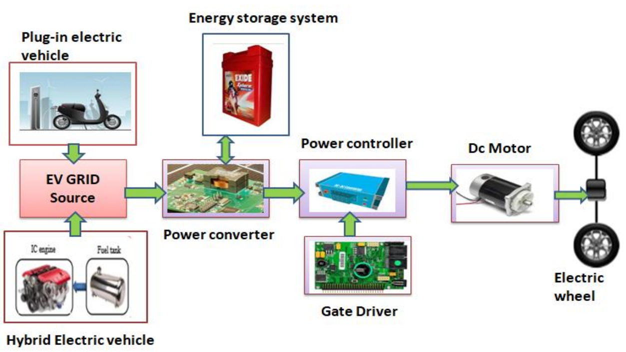

Fig1. Block Diagram of Electric Vehicle

The isolated, non-isolated, unidirectional, and bidirectional power converters used in the Hybrid Electric Vehicles (HEVs) are examined but the design of modulation techniques and the intelligent control schemes are not mentioned [17]. The various power converter topologies and controllers used in HEV applications are discussed even though not mentioned about implementation issues and the categorization of the converters [18].

The capability of EVs and HEVs is analyzed by comparing both permanent magnet and SRM motors. The major advantages of SRM and the limitation of permanent magnet motors for EVs and HEVs are interpreted. Furthermore, comparing three types of motors which is applicable for both EVs and HEVs methods are discussed [19]. The operation of an Electric vehicle that is well suitable for minimal cost is reviewed. Also, the major improvement in a region of electric motors, power electronics, and control systems performance are discussed [20].

A vitally important factor considered for the selective criteria of Electric vehicles is cost, noise, efficiency, and mainly weight [21]. The bulky motor always increases overall system weight which will affect the overall performance of the vehicle and also result in low acceleration. Therefore, Special machines make the efficient choice in the case of Electric Vehicle application since it makes very strong, lower-cost also comparatively lesser weight [22].

The great advantage of adopting a controller in an Electric vehicle is mainly to attain its steady-state characteristics and also dynamic characteristics with lower settling time, quick response, and minimal steady-state errors [23]. Electromagnetic interference will be reduced due to its rapid dynamic response, fewer switching losses, and minimum current stress. Different controllers are used to regulating the DC-DC converters in Electric vehicles [24]. Even though linear converters have a greater advantage with their easy implementation and simple construction; nonetheless, it is inefficient during parameter variation and load disturbance [25].

The controller's modulation schemes used in EV controllers are pulse width modulation schemes, High-frequency pulse-width Modulation, Fixed frequency pulse-width Modulation, Quasi-resonant pulse-width Modulation, Enhanced pulse-width Modulation, Modified pulse-width modulation are reported. However, the different categories of EV controllers, which include intelligent controllers and linear controllers, are analyzed. The optimization approaches with their design, objective function, implementation, computational complexity, and performance are outlined. Furthermore, existing issues and challenges of EV converters, modulation, controllers are explained rigorously [26]. The solar PV array along with the energy storage device and single-phase charging station utilizes energy for charging the EVs. However, power to the charging station is generated from the grid system during the nonsunshine period of the solar PV array. Also, the power generated in the grid is nearly unity that needs to get swapped with the charging station [27].

The various possibility of charging the batteries of the electric vehicles at different locations like colleges, restaurants, hospitals, buildings utilizing the power of PV energy. Also, comparing different kinds of fuel makes consumption stable, and comparing emission of CO_2 gases in conventional type vehicle with distance traveled in EV is examined [28]. The charging station is a standalone generator that will result in higher voltage which has been discussed [29]. Figure 2 illustrates overall the Schematic Diagram of EV Review Methodology.

The most versatile objective of this article is classified into a different section, the various types, and challenges of electric vehicles described in section I. EV converter classification, topologies, operation, its strengths are provided in section II. Different kinds of Electric motors for EVs and their challenges are discussed in section III. EV controller types, control operation, benefits, and shortcomings are discussed in section IV. Solar charging station for EVs is analyzed in section V. The conclusion and future recommendations are discussed in section VI.

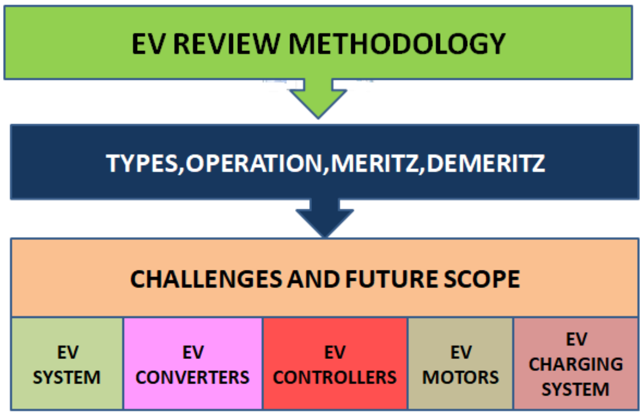

Fig.2. Schematic Diagram of EV Review Methodology

2. Electric Vehicle and Types

General energy storage devices like batteries, fuel cells, and in some applications super capacitors are also used to save electrical power. In recent days AC motor, Brushless DC motor (BLDC), and permanent magnet synchronous motor are used for both EV and HEV applications. The series and the parallel-based connection used for the transmission system in between internal combustion engines (ICE) and electric motors. The different types of control techniques like microcontrollers, Digital signal processing (DSP) are used for different controllers. The Insulated Gate Bipolar Transistor (IGBT), Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), and Bipolar junction transistor (BJT) are various power semiconductor switches used for control techniques. Due to maximum efficiency in EVs and HEVs applications always prefer renewable energy sources (RES).

The various methods of Electric vehicles are Hybrid, Plug-in method, Battery type, Fuel Cell, Regenerative braking. The major important difference between EVs and ICE is i) less damage to the environment, ii) less fuel cost,iii) lesser tailpipe emissions. Figure 3 shows the classification of Electric vehicles.

2.1. Plug-in Electric Vehicles(PHEV)

The plug-in type consumes electricity from the grid to charge its battery and then it utilizes charge from the batteries to run the electric motor. Instead of using liquid fuels, they can primarily power through electricity and outcome with no tailpipe emissions. The different components used in plug-in EV are battery, gear system, motor, semiconductor converter, and power controller. Fig..4 shows the plug-in block diagram of EV. The energy stored in the battery is used to rotate the electric wheels connected to the motor.

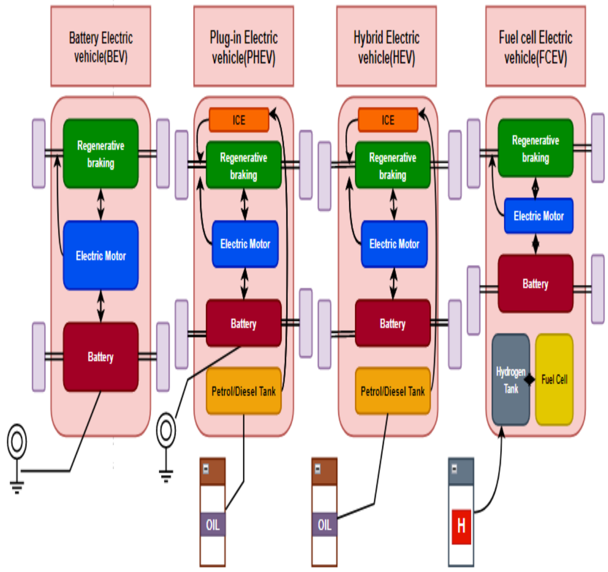

Fig. 3. Classification of Electric vehicles

The major advantages of this system are Eco friendly and no pollution. Similarly, a major drawback in this method is quick battery discharge. Therefore, the plug-in cannot be used for long-distance travel applications [30].

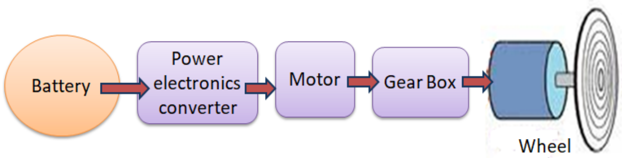

Fig.4 .Plug-in Electric vehicles

2.2. Hybrid Electric Vehicles(HEV)

The Power generated by an internal combustion engine along with the combination of two or more electric motors used to store energy in the battery in an EV is named a Hybrid Electric Vehicle [31]. Compared to conventional vehicle its difference in the power range, have the advantage of lesser and more fuel economy. Nowadays due to their greater mileage and less pollution, the top car companies turned toward HEVs because they became eye-catching among consumers. Table I indicates the hybrids design philosophy for various hybrid %.

Hybridness can either be decided by series and parallel connection of motor/Generator with the powered engine. In which parallel hybrid can possible in all range of % as in table. While the series hybrid has motor power exactly equal to engine power. Hence this exists only on band near Hybrid=50. Outside that range, its hybrid changes into either plug-in hybrid or mixed hybrid. For Hybrid <50 % it is denoted as mild hybrids or small hybrids, similarly, Hybrid >50% or 100% is termed as full hybrid or large hybrid.

Table 1. Hybridness based on the design philosophy

Design	0%	25%	50%	75%	100%
Hybridness	The vehicle is purely powered by a conventional gasoline engine	This region indicates a mild hybrid in which HEV has an engine powered by 75kw and a traction motor with 25 kW. Here both motor shaft and engine are input leads to three-way transmission.	This region indicates a full hybrid here HEV has both a traction engine and motor powered by 50kw. Here also both motor shaft and engine are inputs for three-way transmission.	This region is for plug-in hybrid here HEV has a large Motor compared to an engine with a Motor of 70kw and an engine with 25kw of power. To supply power heavy battery is required.	Here charging station supplies stored energy to the battery. The motor is powered by 100kw in which electrical power is obtained either by battery or through regenerative braking

2.3. Battery Electric Vehicle (BEV)

Battery-type Electric Vehicles are full of rechargeable batteries and no other resources like a gasoline engine. Since the complete energy should be utilized to run the vehicle consumed from the battery pack energy which is recharged from the grid. The major components are converter, electric motors, and propulsion. They have no ICE, fuel tank, or fuel cell instead power is consumed from battery packs The main advantage is zero emissions, lower maintenance, no tax, running cost is low. Similarly, the main drawbacks are battery life, embedded energy used in battery manufacturing, and poor charging capacity.

2.4. Fuel Cell Type Vehicle (FCEV)

The fuel cell method of an electric vehicle is energized only through hydrogen. Compared to other conventional ICE it is more efficient with zero tailpipe emissions. However, they emit only warm air and water vapor. The major merits of FCEVs are very low greenhouse gas emissions, reduced oil dependence, and lesser Air Pollutants [32]. The challenges faced in FCEV are cost, Fuel Cell reliability, durability, getting hydrogen, and public education.

3. Converter Types, Challenges, Configuration

The EV converters can be classified along with their topology, challenges, and control modulation techniques. The converter configuration can be differentiated into two types: one is isolated and the other is non-isolated. For low and medium output power isolated dc converters are used while the non-isolated type converter is suitable for high and medium type power operation [33, 34]. Especially for low or either medium power applications, isolated DC-DC converters are always recommended [35, 36]. Figure 5 shows the converter classification based on isolation and non isolation methods.

3.1. Non-Isolated Converter

Bidirectional DC-DC non-isolated converters categorize as conventional and interleaved converters. Generally non -isolated converter has many advantages particularly, conventional converters are commonly used due to their simple control technique, easy topology, and low cost. However, due to improved efficiency and attractive performance, the interleaved DC-DC converters also acquire to be popular. Table II indicates the comparative analysis of nonisolated converters.

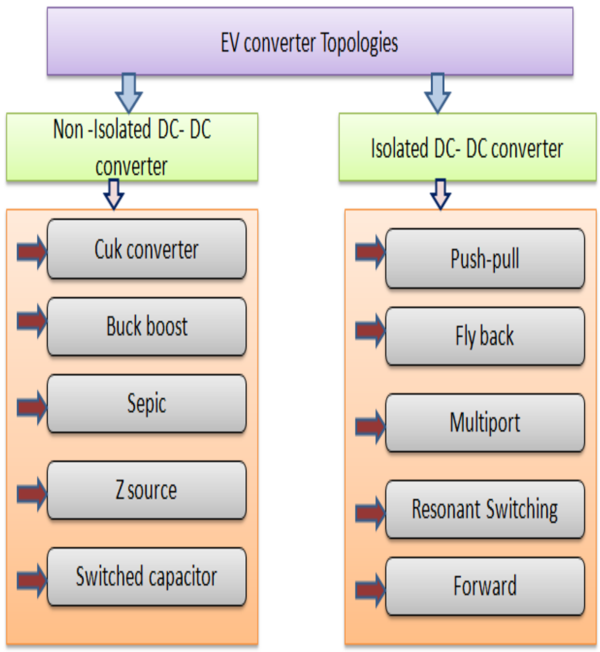

Fig. 5 . Converter classification based on isolation and non-isolation.

3.1.1 Buck-Boost Type Converter

This converter is formed by the combination of two converters which are the buck converter and the boost converter methods. In that output voltage level reduced compared to input level in buck converter and the output voltage level step-up in the boost converter. In various photo-voltaic (PV) energy generation applications the combined converter topology is generally applied to various applications such as standalone method then grid-connected and the drive applications.Furthermore, buck-boost converter topology is less expensive, high efficiency; it offers a low operating duty cycle, minimal components, able to step up or down the voltage. However, the main challenges faced are high gain cannot be achieved due to its poor duty cycle, also there is no isolation between the input to the output side, unsuitable for certain applications.

The double switch buck-boost converter can efficiently use MPPT for solar array purposes further it can maintain flawless efficiency throughout load changing conditions is proved[37]. The hybrid fuel cell in the power system for coupled inductor buck-boost converter results in efficient output reduced ripples and non-inverting output. Nonetheless, the converter used in industries has wider applications for renewable energy resources [38].

A bridgeless type buck-boost converter for drive motor is proposed in [39], to reduce switching and conduction losses integrated buck-boost converter used AC mains as the associated power supply of the drives. Furthermore, this configuration results in a minimum value of filter capacitance and higher efficiency [40].

For electric vehicles [41], a field-programmable gate array (FPGA) is adopted for both controlling and power transfer among the ultra-capacitors and batteries applying interleaved type bi-directional converter. Hence, the system positively resulted between the sources with minimal switching losses [42]. Figure 6(a).shows the buck-boost converter topology diagram with a switch, diode, inductor, and capacitor. Pulse width modulation technique is used for buck-boost converter in which author designed a linear circuit model of converter which can operate in discontinuous mode[43].

3.1.2. Single Ended Primary Inductor Type Converter (SEPIC)

SEPIC topology as shown in Fig.6(b) used in a wide range of applications like power factor improvement in AC systems and also PV voltage generation to regulate the flickering DC voltage. However SEPIC also operates in both buck and boost modes to achieve maximum output voltage during switching operation. Compare to OFF time the ON time will be higher, to attain difficult output voltage. For high power applications, it is always preferred since compared to buck-boost converters it can produce non-inverting output that causes it more prominent. The main advantage of SEPIC is it can produce Non-inverting output in AC lines, it can able to utilize for power factor correction. The limitation is hard to control its duty cycle and results in poor voltage gain.

In SEPIC converter for renewable energy system it attains high power efficiency, minimal switching stress with continuous input current by inductor coupled SEPIC converter for renewable energy system [44]. However, for greater power factor correction topology is enhanced to attain in AC power source using bridgeless isolated SEPIC integrated with slide mode control operates as a single-phase rectifier [45].

An advanced topology with a modified SEPIC converter shows sufficient performance in the power factor correction method and this resulted in minimal total harmonic distortion [46]. Also to acquire less switching stress by lesser input voltage with maximum output voltage for the development of renewable energy operation. For Fuel cell and PV-based applications, a double boost integrated SEPIC method is adopted in which it has two inductors with a single controlled switch [47]. This topology can generate higher voltage gain by avoiding enormous duty-cycle. Figure 6(b) shows the SEPIC topology diagram with a switch, two inductors, two capacitors, and a diode.

SEPIC topology is coupled with dual voltage multipliers with an inductor to attain more voltage gain with reduced voltage stress besides the supply main switch. For sustainable efficient renewable applications, the stable input current is always a good choice. The digital pulse width modulator is used in SEPIC in which the author describes the complete design of high frequency switching for power supply [48].

3.1.3 CUK Converter (CC)

The CUK converter is suitable for power factor correction, voltage regulation, and low ripple application. Electric vehicle implements adjustability to vary the output value to the input voltage. Despite sharing a single magnetic core, the CC can result in better efficiency and low ripple output [52]. Compared to buck-boost converter CC can regulate the inductor ripple current efficiently by using an LC filter.CC has uniform input and outputs current besides, through capacitor it can supply continuous power with low switch EMI. However, due to large current stress and more reactive components, CC attains some losses [53].

To improve power factor a converter was designed for EV charging over the continuous conduction mode utilizing CC here output was simulated and the model was designed successfully [54]. Further, Switched inductor was utilized for the power factor improvement in CC for EV charging application. The output is analyzed with proper modeling, simulation results are verified also converter performance is assessed for total harmonic distortion (THD). To analyze output in accelerate mode and regenerative mode by an electric motor for EV application a PI controller-based CC is designed which can further operate in four quadrants to verify the CC capability[55].

For EV applications the CC topology is designed using two switches, with two inductors and two capacitors, and two switches, as shown in Figure 6(c). This converter can operate both discontinuous and continuous current modes. The pulse-width modulation scheme is used in CC in which the authors achieve nil harmonic current in EVs. The inductor current feedback forms the internal current loop similarly the DC link forms the outer loop control [56].

3.1.4. Bidirectional Switched-Capacitor Converter (BSCC)

The Switched capacitor is the most versatile converter in EV with a Hybrid Energy source to attain a wide range of voltage gain. Also, a synchronous rectifier without extra hardware allows zero voltage at turn on and turn off switching conditions, thereby converter efficiency improved [57-58]. The main limitation of SCBC is more ripple current, also during large output voltage difficult to attain high efficiency.

At minimum temperature self-heating of li-ion battery validated with BSCC reliable operation, high efficiency, low cost, small size since the existing device not suitable for EV application the proposed system designed to achieve efficient self-heating for Li-ion batteries [59].

Hybrid DC converter with BSCC result in low cost and wide energy density by replacing VSI through twice the modulation area also reduces large inductor and high filtering capacitor[60]. With the wide-ranging of potential gain, it's possible to reach minimal voltage stress. The converter is designed at 400 W to analyze its characteristic a balancing topology introduced for series battery and parallel capacitor which is coupled with buck-boost converter [61].

Figure 6(d) consists of a capacitor, inductor, and four switches with operation in both step-up and step-down mode during the charging and discharging period. The pulse-width modulation scheme is used in BSCC in which the author has employed PWM for EVs to generate converter gate signals for both step-up and step-down mode [62].

3.1.5. Z-Source Converter

Z-Source converter is highly suitable in high and medium power applications with great converter topologies. It has merits of lesser ripple noise lower duty cycle, low cost, compact size moderate efficiency compared to other converters. The proposed have achieved 89% efficiency of Z source converter along with multiplier and flyback converter [63].

The proposed topology has a converter-designed fuel cell to achieve constant input to output variable with constant DC link[64]. Here the converter is integrated with a solar PV array with ground have the advantage of minimal size and lower switching stress.

A hybrid Z-source converter for drive-based applications illustrates the maximum voltage and efficiency in EV [65]. The proposed z source topology in EV and transportation has achieved improved power factor for the wireless application without the support of any semiconductor device or with control circuit here power factor correction and the output voltage is regulated successfully [66]. Figure 6(e) shows the Z source topology for EVs which consist of two inductors, two capacitors, a switch, and a diode. Pulse-width modulation is used in the Z source converter in which the authors have designed the PWM generator for EVs application to generate gate signals for both step-up and step-down mode [67].

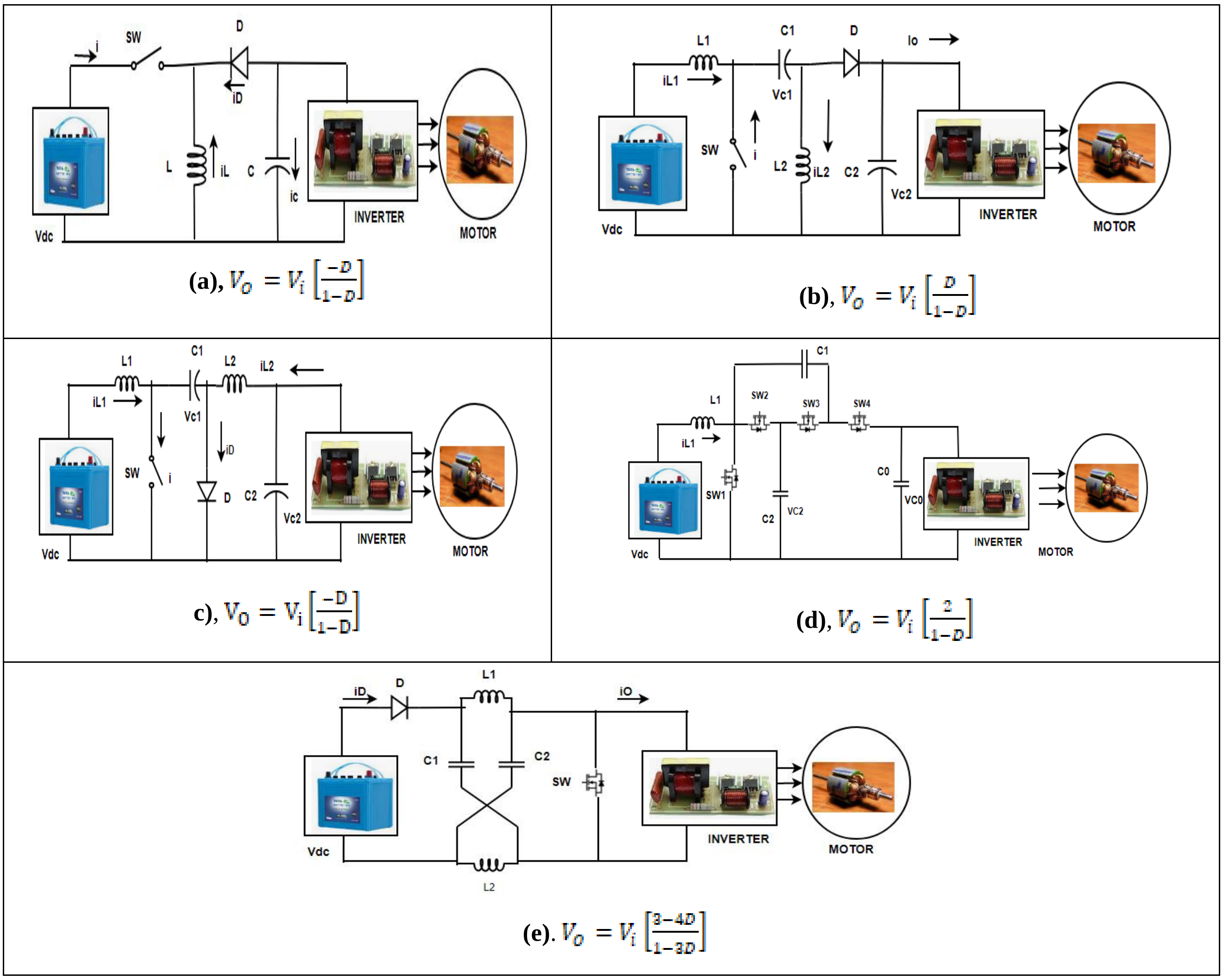

Fig. 6 .Circuit diagram of Non-isolated converters,6(a). Buck-boost converter topology, 6(b).SEPIC topology, 6(c). CUK Converter topology, 6(d). Bidirectional switched-capacitor converter topology, 6(e).Z source converter topology

Table 2. Comparative analysis of Non-isolated DC-DC converter

DC-DC CONVERTER	**SEPIC**	**CUK**	**BOOST BUCK**	**Z-SOURCE**	**SWITCHED CAPACITOR**
Target	To obtain power factor improvement in the AC system	To reduce more energy loss.	To provide minimal switching losses and non-inverting output	To provide higher voltage gain and to get the absolute level of common ground.	-To attain higher efficiency and voltage gain.
Result	-To regulate the flickering DC voltage -Greater power factor correction	-Stable output -Ripple-free output.	-Minimum value of filter capacitance -Higher efficiency	-96.44% of maximum efficiency and to the minimum level of 88.17%,	-Higher Efficiency which is greater Then 90%.
Merıts	-Minimal component required for step-up and step-down -AC lines provide Power factor correction techniques.	-Inductor ripple current reduced. -Input current and output current are Continuous.	-Less expensive -High efficiency -Minimal components	-High efficiency -Lower ratings of components. -Good step-up and step-down capability.	-low cost -Simple design. - output Current is less
Demerıts	-Poor voltage gain. -Hard to control its duty cycle	-Unstable -Difficult to control and damping.	-Low voltage gain -Poor duty cycle	-Discontinuous Input current -Larger Voltage stress.	-More ripple current. - Higher Efficiency cannot be maintained for higher input voltage to output voltages.
Current/Voltage Rıpple	Smooth	Smooth	Moderate	Smooth	Moderate
Swıtchıng Frequency	More	More	More	More	More
Cost	low	Low	Medium	Medium	Medium
Emı Suppressıon	Minimized	Minimized	Needed	Needed	Needed
Cırcuıt Complexıty	Smooth	Smooth	Moderate	Difficult	Moderate

3.2. Isolated Converter

The isolated converter will act as grounding between input supply and output; however, they provide lower capacitance at the output side which were quickly and safely allows multiple dc converters. In general, the PV system with a storage device is critical when this device ground is isolated while the capacity of the battery increases; it is safe to install a DC converter in parallel combination. The EV applications in different isolated converters are explained below. Table III indicates the comparative analysis of isolated converters.

3.2.1. Push-Pull Converter (PPC)

The push-pull converter operates by mutual inductive transformer action which transfers power from the primary to the secondary side for EV applications. This topology has notable merits like high efficiency at peak current, its simplicity, low conduction losses compared to other converters. However, the challenges faced by the PPC are smaller filters, high current and low impedance might occur if switches are turned on at the same time [68].

The proposed topology has been implemented with a three-phase voltage-fed push-pull converter which achieves higher efficiency and lower switching loss for the EV system [69]. However, to reduce very high starting power and primary peak voltage, a peculiar control technique is introduced to achieve a smooth starting mechanism for vehicular application by applying state space design of push-pull converter. Thereby, PPC can achieve low harmonics, efficient output with a low current for EV application [70].

The PPC topology consists of 4 switches, rectifiers, transformers, bypass capacitors as in figure 7(a). In that, when S2 is in on position transformer current flows through s4 and capacitor, then the converter operates in PUSH mode. Similarly when S1 is in on mode, the current flows through the capacitor that time converter operates in PULL mode. The pulse-width modulation scheme is used in PPC topology in which the authors used a control algorithm that is based on a microcontroller to generate a duty cycle for PWM with IGBT used as the gate driver circuit [71].

3.2.2. Flyback Converter (FC)

In the Flyback converter during the ON state, energy is saved while during the OFF state, the stored energy is transferred. However, it is an isolated converter similar to the buck-boost converter which consists of a transformer [72]. It has advantages of more isolated outputs, effective isolation characteristics, low cost, and high voltage output [73].

The FC possesses has certain limitations like more loss, higher input capacitance, and larger ripple current [74]. A FC topology for EVs application consists of a couple of switches and capacitors with isolation transformer as in figure 7(b). Fixed frequency pulse-width Modulation scheme (FFPWM) is used in FC in which the author uses the FFPWM method to assess the EVs electromagnetic interference performance with FC by applying an advanced numerical model [75].

3.2.3. Resonant Converter (RC)

The resonant converter is an electric power type of converter used to resonant at a particular frequency by using a resonant tank. Also, they find major applications in ICs, low switching loss, and high efficiency for EV applications. However, it has certain disadvantages such as transformer design is difficult, heating problem.

The RC topology consists of four switches with a diode, two inductors, and two capacitors as shown in figure 7(c) which can reach maximum efficiency at a low cost[76].

Quasi-resonant pulse-width modulation (QRPWM) is used in RC in which authors suggested this QRPWM scheme by keeping the switching frequency value more than the resonant frequency value. The proposed QRPWM has good performance even at the minimal turn-off loss [77].

The converter resonant frequency is given by

$$F_r = \frac{1}{2\pi\sqrt{LC}}$$

F is the frequency,n is the number of cycles

3.2.4. Zero-voltage switching converter (ZVSC)

The ZVSC can operate FET switching by considering the potential difference between source and gate during the turn on and off condition of FET. However, it has the greater advantage of high power density, less size, controllable for EV power application. For high power applications, it experiences voltage stress, is not fault-tolerant, and needs a larger capacitor for output ripple [78].The ZVS converter also is operated in both buck and boost mode with a topology of four switches, four capacitors with four diodes as in figure 7(d).

An enhanced pulse-width modulation scheme is used in ZVSC in which the author developed eZdSP along with six EPWM modules to generate a PWM signal with high resolution, more flexibility, and its limits instability the in system[79].

3.2.5. Multi-Port Isolated Converter (MPIC)

The isolated multiport converter is mainly used to integrate with various renewable energy for concurrent power management thereby its has improved efficiency. Nevertheless, it has certain drawbacks such as a larger number of switches needed, high weight, difficult synchronization. To achieve a dynamic state, a fast response proposed system is designed and executed along with a power management system. The topology consists of isolated multi-transformer with inductor; diode and switches as in figure 7(e). The Modified pulse-width modulation is used in MPIC in which the author utilized decoupling network and controllers lookup tables with three duty cycles with PWM 100 KHZ pattern to adjust the two-phase lookup table for shift angle[80].

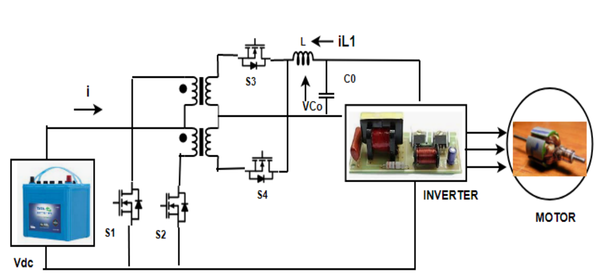

Fig.7(a), $\frac{V_o}{V_i} = nD$

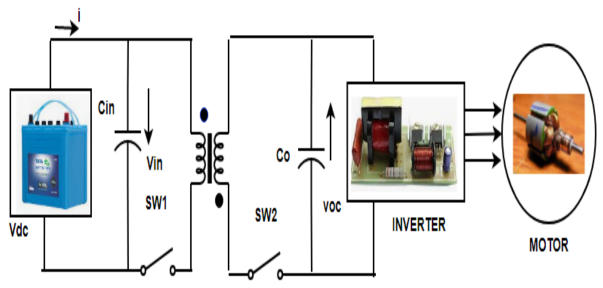

Fig. 7(b), $\frac{V_o}{V_i} = \frac{nD}{(1-D)}$

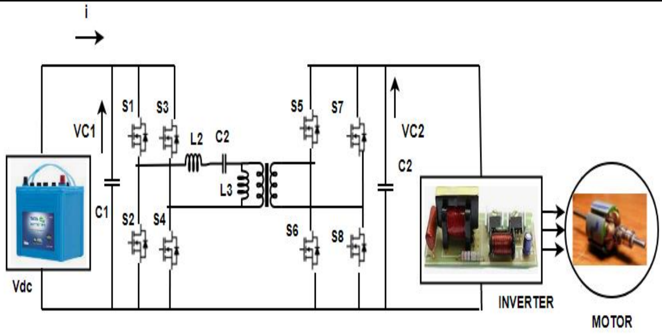

Fig. 7(c), $\frac{V_{out}}{V_{in}} = n(j2\pi F)$

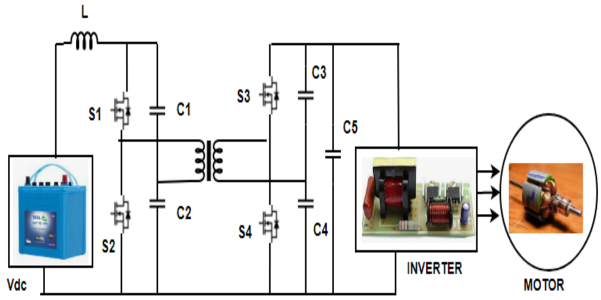

Fig. 7(d), $\frac{V_{out}}{V_{in}} = \frac{2}{n}D(1-D)$

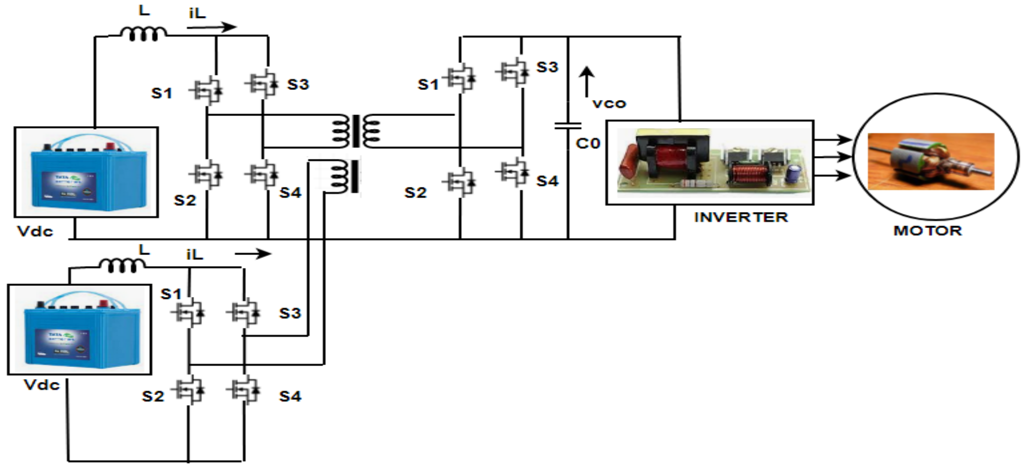

Fig. 7(e), $\frac{V_{out}}{V_{in}} = \frac{n+1}{1-D}$

Fig. 7. Circuit diagram of isolated converters, 7(a).Push-pull converter,7(b).Flyback converter topology,7(c). Resonant converter topology,7(d).Zero voltage switching topology,7(e).Multiport converter topology

Table 3. Comparative analysis of isolated DC-DC converter

DC-DC CONVERTER	PUSH-PULL	FLYBACK	RESONANT	ZVSC	MPIC
Target	-To convert the voltage as DC voltage.	-To provide support for a wide range of input Voltage.	-To reduce Passive filters and the magnetic components	-To obtain different power during Load variations. -To get the soft-switching to Maximum efficiency. -To provide the output voltage For diode bridge rectifier.	-To limit the duty cycle. -To reduce the system overall losses. -To analyze the control techniques and dynamic response.
Result	-In primary side can provide minimal voltage and current. -Starting power	-Leakage inductance can be attained within an acceptable limit.	-step-up and step down The capability will be more. -To obtain high	-Achieves stable operation even in no-load condition -Voltage switching will be minimum under load varying	-Obtain high efficiency from controlling duty cycle and phase shifting - Fast dynamic

	will be reduced		efficiency. -To get high voltage gain.	conditions.	The response can be achieved. -Power flow will be Independent.
Merıtz	- Minimal EMI. -Less filtering - transformers and transistors can be used for better efficiency	- Multiple voltages can be regulated. -Primary circuit can be isolated from the load..	-High efficiency -Low cost. -High conversion ratio	-Reduced interference -losses in switching reduced -Additional clamping is not required.	-Higher gain. -Ripple current is minimum -Efficient Galvanic isolation is provided
Demerıts	-Need Central tap transformer. - Mostly Two switches are not frequently used in flux creation.	-losses will be more -Had ripple current. -Input to output ,the capacitance will be more.	-Controller is costlier -Complex transformer circuit	-Very low fault-tolerant capacity -More capacitor Needed. - Current ratings are high.	-Synchronization is difficult -Need more Components. -High efficiency -Complex analysis duringTransient conditions.
Current/ Voltage Rıpple	Smooth	Smooth	Smooth	Difficult	Difficult
Swıtchıng Frequency	More	More	More	Less	Less
Cost	Less	Less	Less	Medium	High
Emı Suppressıon	Minimized	Needed	Minimized	Minimized	Needed
Cırcuıt Complexıty	Difficult	Moderate	Moderate	Difficult	Difficult

4. Electric Vehicle Motors

Various types in electric vehicle motor for the application of electric vehicle with their configuration is consigned. Also, different motor advantage, disadvantage, and their application are discussed in detail [81]. The layout of EVs consists of the converter, controller, batteries, motor, and control circuits. In general Electric motor is classified as AC and DC motor. Here the Working features, operation, and limitations of all available motors are discussed. Various electric motor used in Electric vehicle is shown in figure 8.

4.1. The AC Electric Motors

Sinusoidal input motors are reviewed in this section. Generally, an all-electric motor has a stator, rotor, windings, air gap, brushes, and commutators/converters. Depending on various components the motor is classified and constructed [82].AC motors are further classified into two types they are discussed in this section. Table IV indicates the comparison data of various motors in EV applications in the market.

4.1.1. Synchronous Motors

Synchronous motors are efficient AC motor works concerning shaft rotation synchronization along with the supply current frequency rotation period will be equal to the sinusoidal cycle.

(i)Permanent Magnet Synchronous Motor (PMSM)

To achieve minimum ripple, torque is driven by an AC signal besides that it is very similar to a BLDC motor [83]. Further, its AC flux density is completely different from a trapezoidal flux in BLDC which is generated by stator winding with the sinusoidal distribution of multiphase supply. PMSM motor possesses high power density with minimal moment of inertia for the same rating compared to an induction motor, even though it has the same stator design to create AC flux density. This motor operates with special drive but it is very efficient, capability to generate torque even at zero speed, large power density. To achieve mentioned advantage this motor operates with variable frequency control drive however it requires careful attention over-speed control. Also, it has high system complexity, cost of the PMSM is comparatively high to the induction motor.

(ii)The Stepper Motor

This motor has a similar structure to switched reluctance motor. Here stator is made up of winding coils and the absence of coil rotor is laminated with soft iron. During the current switching process of stator coils, torque will be produced, to rotate the rotor the switching current generated in stator winding had a certain magnetic attraction to rotate to another stable position. The rotational distance and speed will be determined by the number of pulses and current frequency of the motor respectively. Most suitable for minimal speed application since it can move certain steps typically. Since this is suitable for position control, precision purpose and not ideal for any EV application.

(iii) The Switched Reluctance Motor (SR)

Reactive torque is absent in Switched Reluctance since the rotor has no coils so it cannot produce a magnetic field over the rotor of the Reluctance motor. When the stator coil is supplied, it starts energized due to this, the stator pole gets attracts towards the rotor pole towards adjustment of the poles. Thereby more ripple torque is developed results in vibration and heavy noise in the motor. Beyond this SR motor has a very simple design, is economical, less maintenance with very strong construction. Compare to stepper motor this motor generates low torque so that this motor is not preferred much for EV application

4.1.2. Induction Motor

The induction motor is an asynchronous motor in this torque is generated by the rotor current; this current is produced due to the electromagnetic induction principle from the stator field winding. The rotating magnetic field is produced in the rotor which induces the rotor current by the excitation of stator winding due to Sinusoidal current. The rotor-induced current will further generate the rotor relative magnetic field [84]. Due to frequency variation in rotor and stator magnetic field torque is generated [85]. The induction generally has its advantages like no commutator, no brushes, less maintenance, compact, low cost which makes them very attractive in upcoming EV applications. Nonetheless, it has difficulties in controlling during converter operation of power supply.

4.2. The DC Electric Motor

The direct current supplied input powered motors are reviewed and various challenges faced in EV application are discussed in this section. Generally, DC motors are classified as brushed and brushless by their components are discussed for various criteria like cost, power output, efficiency, application.

4.2.1. Brushed DC Motor

Brushed types DC motor is well suitable for low-budget application since it is driven by DC power with the presence of brushes and commutator in the motor. The commutator will help in converting DC power to AC, while the current starts flowing in the armature winding. Here same polarity magnets will get repelled in an electromagnetic field simultaneously opposite polarity magnets will get attracted. The commutator turns the armature current to get repel from their nearby magnet so that the motor will be in continuous running condition. This motor is preferable for its low-cost application due to its DC input supply. However, it has certain drawbacks like interference commutator heating, friction in brushes, arcing in brushes. So this motor has less interest in EV application but it can be more suitable for high-efficiency applications.

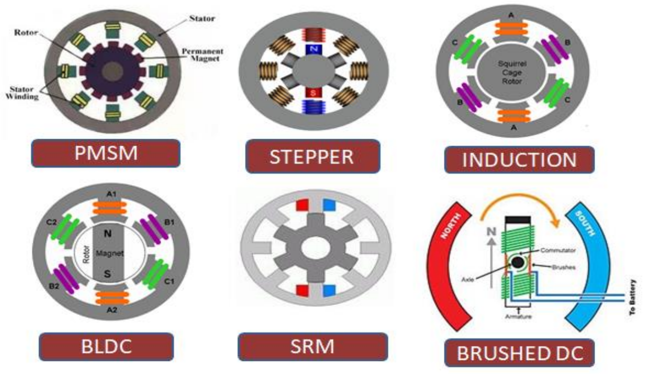

Fig.8. Various Electric Vehicle motor

4.2.2. Brushless DC Motor

Brushless DC motor is a most versatile motor which has has been accomplished with electronic commutation used to determine the current switching in rotor position. However, the BLDC stator is wounded with coil and the rotor is made up of a permanent magnet. Hall Effect sensor plays an important role since it is placed on the rotor which senses the position of the rotor during energization so that winding can be sequentially energized.

In automotive industrial applications also BLDC motor is often used for electric vehicle application due to its high efficiency. Also, it has great advantages like less maintenance, low losses, compact compare to another motor, less space it is well suitable for EV. In BLDC instead of brushes, it has electronics commutation which plays a vital role. In PMSM and BLDC rotor will do the excitation process and it has a rotor position sensor for commutation [86]. Since it has certain disadvantages like cost, breakdown of the sensor, need regular maintenance; it has iron losses, temperature sensitivity. However, the iron loss can be reduced by the cooling system. The magnetic characteristics will limit the overload of PMSM and BLDC motors.

The energy density of the PMSM motor is normally high because this motor has the advantage of minimal space [87]. During the moment of high speeds, the stator loss increase which decreases the efficiency of PMSM and BLDC motor also field weakening in the motor is executed by the current component considered as the main drawback. BLDC is more popular due to its less mechanical noise, low EMI, high efficiency, high power density to EV application.

Table 4. Represents the comparison data of various motors in EV of 40kw power [88].

Types Of Electric Motor	**Maximum Power kW**	**Maximum Current A**	**Mass Of Motor Kg**	**Efficiency**	**Application**
DC Motor	40/54.4	410	92	0.75	 Peugeot-Citroen
Switched Reluctance Motor	40/54.4	250	32	0.95	 Holden/Ecommodore
Permanent Magnet Synchronous Motor	40/54.4	192	26	0.94	 Nissan/Tino
Induction Motor	40/54.4	500	70	0.85	 Renault/Kangoo

5. Electric Vehicle Controllers and Challenges

To attain regulated constant voltage for the converter to choose a suitable controller is essential at various switching operations. During heavy load conditions and variations of system values, certain control techniques exhibit inefficient output. Since to achieve satisfactory performance, to get a fast dynamic response, to bring about very strong controllability, quick response, intelligent controllers are introduced [89]. Here different kinds of control techniques shown in figure 9 with their features, destination, improvement, advantage, and disadvantages are discussed for EV application. Table V indicates the controller's comparison based on challenges and techniques.

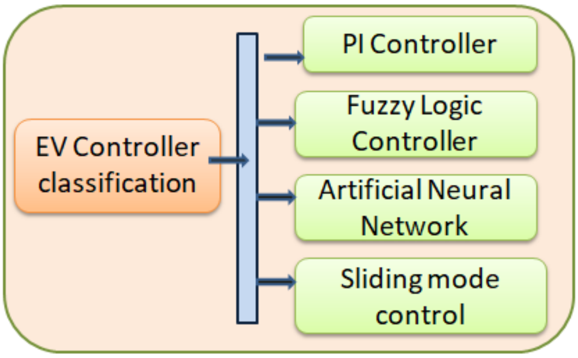

Fig. 9. Controller Classification of Electric vehicle

5.1. Proportional–Integral Control Techniques

The PI controller has a greater advantage such as quiet design, fast output despite it depending on a specific mathematical model, during non-linear and dynamic operation it is unstable, week transient response. The error signal which is generated due to the reference and output voltage signal is feedback applied at the PI controller will increase the system stability [90]. The PI controller can be used for various EV applications such as to improve battery life by adopting multiple energy sources, increase the stability of integrated charging stations, to control multi-level bridge converters. Also to reduce error occurs between the constant references current and active current components. PI controller assures unity power factor by minimizing steady-state error [91].

5.2 Fuzzy Logic Controller

The fuzzy logic controller is always preferred for its smooth, quick, flexible response, has advantages of reduced ripple current, fast and excellent dynamic response, operate at the nonlinear system. It faces certain drawbacks such as needing knowledge about upgrades in fuzzy rules, need to be expert in designing, up-gradation in fuzzy rules is heavy tasks [92]. Fuzzy controllers act as proper coordination between the battery storage system, supercapacitor, fuel cell, and load. Also, the PI controller is applicable for overcharging purposes but the fuzzy controller is used for ideal power sharing[93].

Fuzzy control has two types of function are Neuro-Fuzzy Logic Control and Fuzzy PI Control. The flexible neuro-fuzzy logic system is a sequence of fuzzy logic and neural networks, thereby it executes faster and accurate responses. Artificial intelligence control operation is introduced with high control complexity, here a mathematical model is not necessary. The Neuro system can handle all types of systems. For EV system it has negligible control suitability with Flexible controllability [94]. The neuro-fuzzy controller has the advantage of very Accurate and robust operation at varying loads with a higher transient response. This controller has complexity in computational problems also not suitable for fast switching conditions, operating under costly processor devices [95].

For HEV application energy management system is employed to avoid overcharging or discharging power-sharing for low pass filters by adopting Fuzzy PI control. In the DC-DC converter both the control, techniques are used for current adjustment in the battery while exceeding the maximum limit [96].

5.3. Artificial Neural Network Control

Artificial intelligent control-based neural network EV application is proposed with LLC converter achieves high efficiency with longer battery life. This control technique needs Artificial intelligence control operation instead of separately mathematical model not required also it has an excellent dynamic response with easy complexity [97]. Further, this method can able to handle all types of systems. Intelligent control neural control has great advantages such as efficient operation under different loading conditions, flexible control, robustness, and has greater accuracy, high transient response [98]. Besides it has complexity in the computational process, not suitable during fast switching conditions, it works on costlier processors. ANN can attain total harmonics distortion of nearly 96.2% with low harmonics and high power factor [99].

5.4. Sliding Mode Control

A sliding mode control technique is applied to receive tracking current control in EV application for boost controller. This technique has nonlinear control operation with very high control complexity [100]. However, this method requires a mathematical model for controlling purposes in which it can handle all types of systems. The system exhibits a very good dynamic response with negligible Control suitability. By adopting this sliding mode type control the system stability can be improved with easy execution of voltage at varying load conditions. But during frequency change the filter design of both input and output effects. While during large control complexity it is difficult to choose suitable parameters. In EV application during load variation or under-voltage fluctuation occurs in switching frequency [101]. This method does not require any additional sensor under converter load and input voltage variation.

Table 5. Controllers comparison based on challenges and techniques

Controllers	**Proportional–Integral Control techniques**	**Fuzzy Logic Control**	**Artificial Neural Network Control**	**Sliding Mode Control**
Achievement	-Output current and input voltage controlled. -Error between active current inner loop component and reference current is reduced.	-Resulted in high efficiency. -Power demand, voltage, current are controlled. -Interface occurs between DC link voltage, generator, and ESS.	- Life expectancy of the battery will be high -Low harmonics, high efficiency, a large power factor can be achieved.	-Control of current tracking can be achieved.
Contributions	-Zero current components can be attained. -Unity power factor -steady-state error reduced. -Balanced power flow achieved.	- Sufficient Conditions satisfied for traction operation. -Coordination will be proper between load, ESS, BSS, SC, FC systems.	-With maximum efficiency, THD will be low, with high ripple voltage.	-Steady-state will be reached with the ESS. -large robustness. - Transient time will be a minimum 80% while starting.
Mathematical modeling	Required	Not required	Not required	Required
Dynamic response	Medium	Very High	Very high	High
Control suitability	Lower order systems	All types of system	All types of system	All types of system
Capability to handle complexity	Difficult	Very easy	Easy	Easy
Sensitivity	More	Less	Less	Less

Control operation	Linear	Artificial intelligence	Artificial intelligence	Non-linear
Advantages	-Execution will be simple -Compact design. -Despite inappropriate tuning operation is unstable.	-Nonlinear system can be handled -fast and smooth response, flexible, Robust. -Excellent dynamics and Transient response.	-Even during load varying conditions attain satisfactory performance. -Robust -Accurate. -Flexible controllability.	-Highly stable -Robust -Reliable -Good dynamic response. -Simple execution.
Disadvantages	-Improper transient response. -mathematical modeling is needed. -Not suitable for time-varying and nonlinear systems.	-Need regular updates in fuzzy rules -Expert knowledge is needed for controller design. -Fuzzy rules generation needs a laborious task execution.	-Need expensive processor devices. -Highly computational problems. -Not suitable for fast switching conditions.	-Control complexity is more which challenges parameter selection. -During load variation Its fluctuates. -Frequency variation largely affects the filter designs.

6. Charging Station, Types, and Challenges

Electric vehicle station is an important aspect in Electric vehicle structure in which supplies energy for charging from different kinds of energy sources. Charging stations classify based on different criteria as follows like power flow direction, power supply, power grid integration, power levels, mobility.Fig.10 shows the charging station classification based on various criteria.

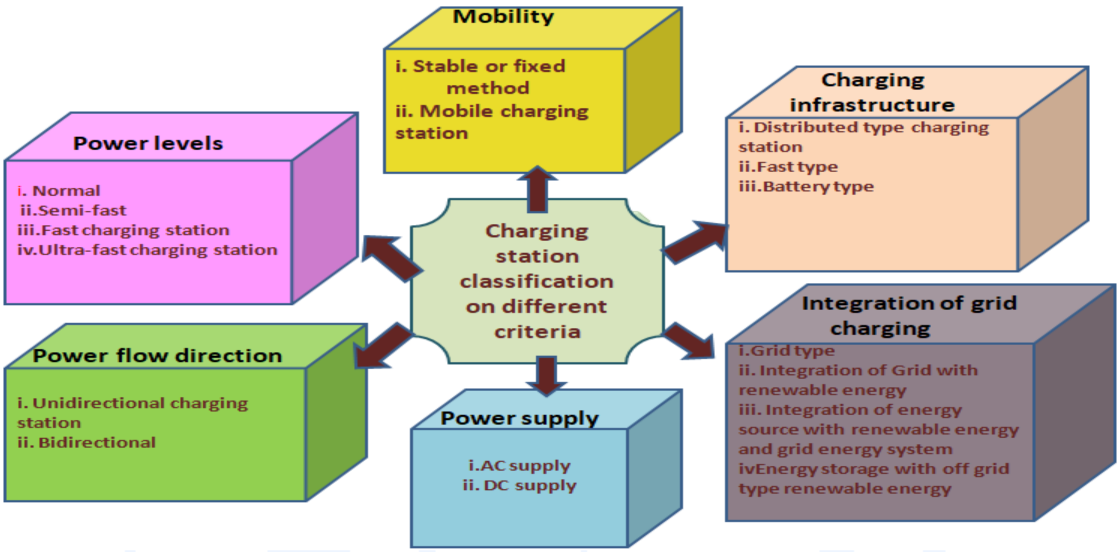

Fig. 10. Charging station classification

6.1. Charging Station Classification on Different Criteria

The Charging station is mainly classified accordingly to attain its maximum efficiency, low cost, easy consumables based on the following criteria they are based on power supply, integration of grid charging, power levels of charging, infrastructure, mobility, power flow direction. The figure11 shows the different models of charging stations for EVs.

6.1.1. Classification of the Power Supply for EVCS:

Based on the power supply given to the Electric Vehicle charging station it can be classified as [102]

(i)AC power supply

In EV application by using AC supply for minimal load application it can charge more number of vehicles with easy installation and cost also low. Usually, an AC charger will consume power from 3.3 KW to 7.4 KW per vehicle charging.

(ii)DC power supply

For EV car applications with minimal charging more cars can be charged with high speed, nearly 7 times higher compared to AC chargers. The main disadvantage of a DC charger is for a higher load and it consumes 15KW. Most residential areas get sanctioned for such high load capacity for heavy vehicles.

6.1.2. Classification on the Integration of Grid Charging

(i)Grid type charging station: Power from the main grid system is the only energy source to charge a battery of EV.

(ii)Integration of Grid with renewable energy type charging station: Power from the grid and renewable energy is supplied to charge the EVs; this renewable energy source has merits that limits the charging load in Electric vehicle on the grid.

(iii)Integration of energy source with renewable energy charging station and grid energy system:

Here energy storage system like battery, the supercapacitor is introduced along with renewable energy and grid system so that grid dependency is greatly reduced in EV charging condition.

(iv)Energy storage with off-grid type renewable energy source: Power from the energy source and renewable energy system is used to charge EVs. This energy storage system is introduced to stabilize the renewable energy system's intermittent nature.

(v)Without energy storage off-grid type renewable energy source: Power is generated only from the renewable energy source to charge EVs.To satisfy the power requirement in EV stations generally two or more systems are connected like solar, wind, hybrid systems.

6.1.3. Classification on Power Levels Used for Charging

(i)Normal charging station: Most suitable for residential installable of a power outlet for EV charging system normally rated in the range of 110 V/15 A.

(ii)Semi-fast charging station: Most suitable for commercial areas, large buildings, some residential areas of current outlet which may be too high to normal rated EV charging in the range of 220V/30A

(iii)Fast charging station: Compared to other industrial or residential power output this method indicates fast charging within half an hour in the voltage range of 400 V,80, or 200A for various power ratings like 36KW,90KW,240KW

(iv)Ultra-fast charging station: This method indicates very fast charging compared to other applications, output in the range of 800VDC.

6.1.4. Classification on Charging İnfrastructure

(i) Distributed type charging station infrastructure: In this method, units are distributed to various places like a shopping mall, office, schools, home, etc by either normal charging rates or semi-fast charging rates.

(ii)Fast type charging station infrastructure: In this method higher range of power is used to charge the EV system by the fast-charging station at a specified location during a very short duration time.

(iii) Battery type swapping station infrastructure: To limit charging time this method is adopted with swapping battery type, here battery is swapped with a completely charged EV battery

6.1.5. Classification on Mobility

(i) Stable or fixed method charging station

Fixed charging stations in EV are mostly plug-in type which is immobile consumers can charge the battery of the vehicle, charging can be done either in the home or in any charging station.

(ii) Mobile charging station

In the EV market, the mobile charging station place major with its different size, attractive power supply have both fast and slow charging based on the requirement. Mobile charging uses battery storage, in which consumers can able to locate charging stations like mobile ATMs. Companies like 'EzUrja' are planning to open mobile charging in all cities and highways.

6.1.6. Classification on Power Flow Direction

(i) Unidirectional charging station

A unidirectional charging station in EV denotes that energy can flow through only one direction either from the grid to the electric vehicle or from the electric vehicle to the grid. The power supply can be at any level like levels 1, 2, 3. Absence of degradation due to discharging in the battery. Less infrastructure cost, easily controllable, without any reversal reactive power, is available for all charge rates. The voltage and frequency control can be achieved. The current phase angle in unidirectional helps the reactive power to supply charging without discharging in the battery.

(ii) Bidirectional charging station

In Bidirectional charging station is the one in which EV charging flows in two ways. It has a lot of advantages like high safety, protection even in Anti islanding, reduced grid losses, higher voltage level stability, better load, and both active and reactive power can be achieved. However its cost is high, needs two-way communications, device stress is high, infrastructure is complex, energy loss is large, it also needs additional sensors and smart meters.

6.2. Challenges and Technological Developments in Charging Station

To increase the development of electric vehicles it's necessary to ensure easy adoption, quick recharging facilities to customers should be convenient and reliable. To decrease the dependency on high rate fossil fuels the only option is to shift to pollution-free electric vehicles. So it's necessary to consider its challenges, aspects, recent development, and research for the various charging stations. Figure 11 shows the charging station models for Electric vehicle.

The following aspects are considered important challenges in EV charging stations.

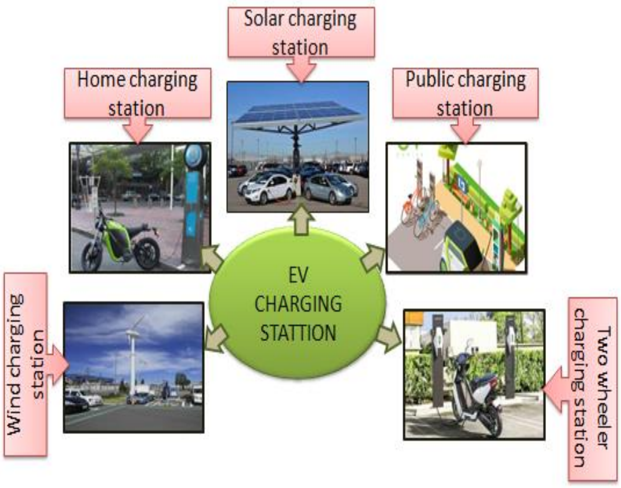

Fig. 11. Charging station models for Electric Vehicle

6.2.1. EV Charging Stations Based on Location

Optimal location of Electric vehicles plays a major role among consumers which mainly depends on the cost of operation, operator charging satisfactory, Easy availability, vehicle power loss, traffic, safety in the power grid. By Considering various factors some charging stations like DC fast-charging stations it's adapt to choose a location on highways, but it has challenges like charging demand, facility, electricity cost, installation, maintenance. However other ones like a Public charging station Plug-in electric vehicle charging station, Fast charging station (FCS) are mainly installed to reduce overall cost and studies conducted in various countries [103].

6.2.2. EV Charging Station Optimization Based on Infrastructure

In spite of serving more EVs at a similar time, it needs a larger number of chargers in the charging station but results in larger construction cost and require more electricity. Besides to attain proper optimization of charging station need to satisfy good planning in size and charging station location[104]. The battery size and also power rating are the major factors to be considered in charging infrastructure so that is likely to increase in upcoming years[105]. The EV charging planning process is tedious work which includes technology for energy storage, number of chargers required, decision making, location or space requirement, time management, smooth charging process, etc[106].

6.2.3. EV charging time management by fast, ultra-fast charger development.

Fast charging and ultra-fast technique of charging stations will reduce charging time so that its plays important role in increasing interest over consumer EV acceptance[107]. The EV application adoption rate affects the profit, operation, and development of fast charging conditions [108]. Further, stability of grid system, efficiency, resilience will also be affected by this adoption[109]. A battery-swapping station (BSS) is an advanced method introduced to replace a drained battery with a completely charged battery to reduce the EV charging time [110]. In a fast-charging station, two new methods are adopted to predict charging points required in the future by analyzing daily demand, charging rate, daily future demand to consumer's expectations. To extend the battery life span an algorithm is proposed for energy management operation with a hybrid charging method during peak demand loading conditions [111].

6.2.4. EV Charging Station Communication System

The EV communication system needs standard protocols which include an electric on-road vehicle system and an onboard electric communication system. The smart grid needs suitable communication algorithms for EV charging. For protocol development, both utilities and vehicle manufacturers' criteria should be included.

6.2.5. EV Charging Station Based Strategy-Management

In order of compensating between higher demand in charging of one station otherwise lower demand of charging in another, it's necessary to schedule or correctly regulate available power to charge the Electric vehicle[112]. The study has an algorithm designed for grid systems with bidirectional charging stations of energy trade which provides efficient service to the grid [113].To maintain appropriate Energy balance in charging station of grid station proper structure is important in the transport sector.

Table 6. Challenges in Electric vehicle charging station

Document title	**Authors**	**Year**	**Cite count**	**Research question**	**Research method**	**Research result**
Feasibility of Grid-connected Solar-wind Hybrid System with Electric Vehicle Charging Station	Shakti Singh, Prachi Chauhan, and Nirbhow Jap Singh	2021	5	How does one know the Feasibility of Grid-connected Solar-windHybrid System with Electric Vehicle Charging Station?	Algorithm used: ABC Algorithm and PSO Algorithm	❖ To reduce the sizing of components in hybrid system in- corporate to EV station an operational strategy and mathematical model were derived. ❖ The wind and solar capacity of 20KW and 36kw and 10 KW of purchase capacities are analyzed.
System	Samir M.			How possible a	The circuit	❖ To maintain unity

Design and Realization of a Solar-Powered Electric Vehicle Charging Station	Shariff, Mohammad Saad Alam, Furkan Ahmad, Yasser Rafat, M. Syed Jamil Asghar, Saadullah Khan	2020	24	System Design and Realization of a Solar-Powered Electric Vehicle Charging Station?	model is designed and developed through MATLAB/Simulink, its methodological model is derived to define design features	power factor through PFC, the filter circuit is introduced in the output terminal to maintain a low ripple current. ❖ In the cascade connection of the buck converter, a boost rectifier has been suggested. ❖ The mathematical modeling of circuit operation for the charging condition in CCM mode has been examined.
Electrical Safety Considerations in Large-Scale Electric Vehicle Charging Stations	Bo Wang, Payman Dehghanian, Shiyuan Wang, Massimo Mitolo	2019	46	How do Electrical Safety Considerations in Large-Scale Electric Vehicle Charging Stations formed?	The framework of risk management for EVCS includes 1) risk control 2)EVCS safety considerations 3)risk assessment	❖ To ensure safety consideration in the EVCS environment and other standards they need to follow guidelines, flash boundary, periodic inspection, maintenance, grid interoperability are discussed.
Distributed Scheduling and Cooperative Control for Charging of Electric Vehicles at Highway Service Stations	Azwirman Gusrialdi, Zhihua Qu, Marwan A. Simaan	2017	76	How a Distributed Scheduling and Cooperative Control for Charging of Electric Vehicles at Highway Service Stations analyzed?	The distributed scheduling algorithm is incorporated to control for individual EVs	❖ This paper proposes highway charging.Initially through local information by adopting distributed algorithm uniformly utilized charging stations are designed.Formerly based on V2I and V2V . ❖ Driver's negotiation strategy developed and battery levels are designed to meet the scheduled range.
Optimized Plan of Charging Stations for Management of Demands: An Emerging Need of Hybrid Electric Vehicle	Mojgan Bashiri, Nastaran Bahadori	2016	5	How Can we Optimized Plan of Charging Stations for Management of Demands: An Emerging Need of Hybrid Electric Vehicle?	Life Cycle Cost Analysis(LCC) methodology adopted for calculating cost during the investment maintenance and replacement in storage systems	❖ To reduce cost and also to improve the load profile of the network, the fast charging optimal station is introduced. ❖ Here flywheels are considered for energy storage for their high efficiency, long life, minimal LAC.
An Anonymous Authentication Scheme for Plugin Electric Vehicles Joining to Charging/Discharging Station in Vehicle-to-Grid (V2G) Networks	Chen Jie, Zhang Yueyu, Su Wencong	2015	24	How does an authentication Scheme for Plugin Electric Vehicles Joining to Charging /Discharging Station in Vehicle-to-Grid (V2G) Networks formed?	V2G Networks Architecture, Bilinear Pairings, NNL Framework, Vector Schemes, Revocable Group Signature is Analyzed.	❖ This paper proposes an efficient also secured authentication scheme applying the V2G network. ❖ The scheme provides charging /discharging also authentication features, integrity, Confidentiality also provide correctness, non-frame ability, anonymity, traceability with PEV's dynamic issue management.
Design and Evaluation of Charging Station	Julian Timpner, Lars Wolf	2014	82	Explain the design and Evaluation of the Charging	Parking management, charging station scheduler	❖ This paper explains design scheduling for parking systems along with an efficient automatic recharging system

Scheduling Strategies for Electric Vehicles				StationScheduling Strategies for Electric Vehicles?	includes Static Scheduling, Dynamic Scheduling implemented and explained	which makes a greater offer for EV drivers. ❖ Due to deficiency in battery capacity, charging time design makes station efficieny
Traffic-Constrained Multiobjective Planning of Electric-Vehicle Charging Stations	Guibin Wang, Zhao Xu, Fushun Wen, Kit Po Wong	2013	296	Explain the Traffic-Constrained Multiobjective Planning of Electric-Vehicle Charging Stations	For optimization Data-envelopment analysis (DEA) method, cross-entropy (CE) algorithm applied**.**	❖ This paper explains the planning method of EV charging stations by reducing power loss and deviation in voltage. ❖ The charging station reduces the sizing and the location traveling distances to minimize losses. ❖ Case studies analyzed for construction plans of charging stations for improvement in the economy.
Spatial and Temporal Model of Electric Vehicle Charging Demand	Sungwoo Bae, Alexis Kwasinski	2012	373	How the Spatial and Temporal Model of Electric Vehicle Charging Demand analyzed?	A mathematical model is derived for fluid dynamic based Traffic model also M/M/s queuing theory.	❖ This paper proposes charging demand by mathematical model for highway charging station by space and the time method. ❖ Charging demand in wireless communication concept of the fluid-based traffic model also temporal and spatial model of the charging station is analyzed.
The Planning of Electric Vehicle Charging Station Based on Grid Partition Method	Shaoyun Ge, Liang Feng, Hong Liu	2011	175	Explain the Planning of Electric Vehicle Charging Station Based on Grid Partition Method?	Location is selected best based on Genetic Algorithm	❖ This paper denotes EV planning for charging station location and sizing based on the EV grid. This method reduces losses due to the charging stations. ❖ However this method reduces traffic density, the final result is made by a global solution**.**
Rapid-Charge Electric-Vehicle Stations	Mehdi Etezadi-Amoli, Kent Choma, Jason Stefani	2010	329	How the Rapid-Charge Electric-Vehicle Stations can be predicted?	Modeled and analyzed based on a study of Power-Flow, Short-Circuit, Protection, Load Simulations, MATLAB/ PSCAD Simulations	❖ To achieve fast charging within utility this paper explains power flow, protection, short circuit results in the company ❖ This charging station is a rapidly dependent on-site system utility.
Management Information System of Charging Station for Electric Vehicle (EV)	Yunyan Wang, Jingxin Li, Jiuchun Jiang, Liyong Niu	2005	29	How is the Charging Station Management System Information for Electric Vehicle (EV) analyzed?	Methodology considered on an RS-485 network, output analyzed through charging algorithm	❖ The paper proposes the charging station fully digital system for smart management which analyzes the requirement of the system. ❖ By analyzing voltage and current automatic charging control in real-time is designed for EV system.

7. Conclusion

This review presents different types of Electric vehicle drive with its merits and complexity is discussed. In which Hybrid Electric Vehicle has less pollution and greater mileage capacity. Secondly, the different topologies, operations, merits and demerits of various types of converters implemented in EVs are discussed. Each converter has unique features due to its topology. Among these non-isolated converters, buck-boost converter delivers efficient output with low cost but due to poor duty cycle high gain cannot be achieved. Cuk converter offers broad-range of voltage gain, however, due to its cascaded structure it offers low power efficiency. SEPIC converter attains low switching stress, high power efficiency but difficult to control its duty cycle and results in poor voltage gain. BSCC possess higher efficiency due to its zero voltage at turn-on and turn off switching condition but limited due to its high ripple current. Z- Source converter has low switching stress with maximum voltage gain, has drawback in high capacitance voltage stress.

While in isolated converters by considering PPC having the advantageous of reduced conduction loss but have drawback of high current and designed with center tapped transformer. The FC generates multiple voltages however it has ripple current and interference. The RC has high efficiency but its transformer design is complex. The ZVSC suffers from EMI and switching loss also had a poor fault-tolerant capability. The MPIC advantage in voltage gain but larger components, high sensitivity and ripple current.

Thirdly to determine a well-suited electric motor for EV application various motor efficiency, power density, its advantage, and limitations are discussed. The SRM is identified as most versatile with its simple design, low cost, fault acceptance, easy construction compare to BLDC and PMSM in case of even in power density, low noise, and higher torque. So based on comparative study SRM is much better than other motors.

In the fourth section, by reviewing the controllers help to identify the suitable controller by analyzing its performance efficiency for EV applications. Various controllers, basic operations, topology, benefits, and disadvantages are presented neatly. The intelligent controller has an advantage such as robust, highly accurate, good dynamic response. Even though PI controller is simple to design and cost effective, in time-variant and nonlinear system its performance is poor. So intelligent controller is well suited for EV drives. Lastly, this review paper explores the various types of charging stations for EVs and challenges faced by charging station are tabulated. This review further proposes some unique research work for future advancement in operation of Electric vehicle as follows:

❖ The converter topologies face problems generally as current stress, low impedance, less voltage, higher ripple. Since it requires optimized electrical design for maximum temperature condition to achieve low loss and high frequency. Further to obtain high power density, more efficiency, and high reliability mechanical design is needed to be investigated.

❖ Future scope of research works depends mainly on proper material selection of the converter like gallium nitride (GaN) and silicon carbide (SiC) which has large switching frequency, less thermal loss and high reliability.

❖ Advancement in intelligent control techniques has fast tracking capability, high efficiency, used in DC link voltage control but has drawback such as expensive ,training operation is larger process, data integrity ,parameters should be suitably selected it needs further investigation in computational complexity.

❖ For EV technology better understanding various types of charging station is described, for further understanding commercial and prototype electric vehicle range, charging time, size of battery and charger power.

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