Analysis of DC-DC Converter for Energy Management in Electric Vehicle

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Abstract
The aggravations occurring in Environmental pollution and the exhaustion in fossil fuels has led to the higher cost of Internal Combustion Engine (ICE) based vehicles. Hence, to overcome this critical condition, the Electric Vehicles (EVs), in which the energy storage system plays the main role is introduced. Many countries have moved forward in accepting the use of Distribution Generators (DGs) and EVs. Nevertheless, the uncoordinated charging of EVs led to significant increase in the network losses, decrease in the energy efficiency and system voltages. Hence, the PV (Photovoltaic) System, which is one of the RES (Renewable Energy Sources) is integrated with EVs, so as to eradicate all the above stated issues. However, charging complexities occurs, owing to the intermittent nature of solar system. Therefore, Power electronic converters, along with different controllers are employed for regulating the PV output in EV charging system, in consideration with the economy, as well as the reliability of DS. In this paper, the various types of DC-DC converters employed in EV charging and the different controllers used in charging are analysed with respect to their performances and functioning characteristics. In addition, an analogization is carried out amid the different EV charging techniques, so as foreshow the optimal one.

Keywords:-Internal Combustion Engine (ICE), Electric Vehicles (EVs),Distribution Generators (DGs),DC-DC converters, Comparative analysis

1. Introduction

The world is moving towards clean energy resources, in order to decrease the carbon emission and to decrease the global warming effects. From the Paris agreement, it is identified that about 180 countries have accepted to follow up the regulations that assists in reducing the Carbon emission. Hence, the use of RES has been attaining great heights and its involvement in smart grid system gets higher attention [1]. Besides, as there is great exhaustion in the oil resources, also the aggravation caused in environmental pollution, lead the researchers to focus on EVs, which provides better reduction in energy consumption and air pollution [2]. Nowadays, many developing countries has been focussing on the development of EVs and Distribution Generations (DGs) [3] and the vast increase in these systems lead to many different changes in the power flow process and in the energy consumption profiles [4]. As there is rapid increase in environmental issues, the EVs gets increased attraction from the governments of different countries. Moreover, the total energy consumption ratio decreases, when EVs gets integrated with power grid and this mainly relies on the charging and discharging operation.

Besides, the fast enhancement in EV production, makes EV, an additional load to the existing power system and hence only by using appropriate control techniques, it is possible to protect the power grid from getting overloaded. Besides, the EVs, as an efficient load helps in reducing the peak shape and load profile, which is performed based on the charging and discharging schedule [5]. However, to regulate the charging and discharging functions, proper converters has to be employed. The rapid increase in the power electronics topology, lead bi-directional DC-DC converters to be employed in RES, EVs and Microgrids, which further assists in better power flow amid the different energy storage devices. In recent times, many novel high gain DC-DC converters are introduced, however, there exits limitations in the voltage range. Moreover, these converters does not involves any grounding conditions amid their inputs.

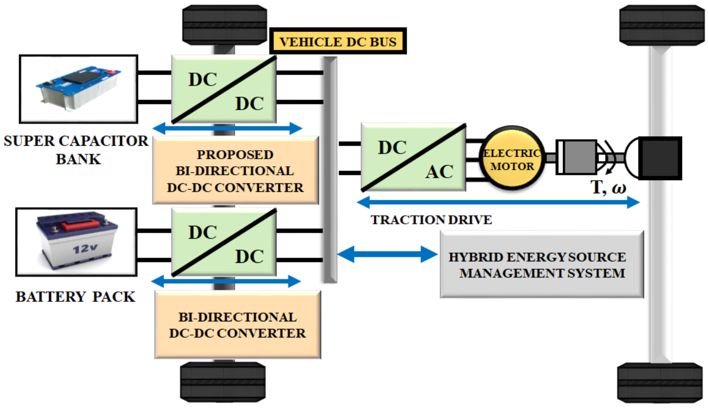


Figure 1. Hybrid energy sources system used in EV charging.

Therefore, Full bridge phase shifted and Fly back converters are employed.Figure 1 illustrates the general configuration of the Microgrid system. When it is not necessary for any galvanic isolation, conventional buck-boost converters are employed, in case of bi-directional power flow. Besides, other bi-directional converters are also employed in certain types of energy storage systems.In consideration with converters, every single converter possess its own pros and cons, with respect to component count, voltage stress and voltage gain. Moreover, with the addition of capacitors, switches and inductors along with conventional buck-boost converter, it is possible to improve the performance further. Moreover, there are possibilities to modify other converters like Cuk, SEPIC and Zeta converter for bi-directional topologies, however possess limitations in attaining the required efficiency [6, 7].

In [8], it is specified that by employing enhanced converter topologies in battery charger, the possibilities of attaining better EV charging structure improves. The proper functioning of battery charger completely relies on the switching techniques and the control techniques involved. Moreover, many different types of algorithms are employed for regulating the converters, microcontrollers and integrated circuits. Figure 2 illustrates the EV power architecture of battery Charging system.Further, to provide independent control over the real and reactive powers, a decoupling method is employed in this work. This proposed technique uses a PI controller for regulating the real and reactive power attained, leading to better dynamic performance.

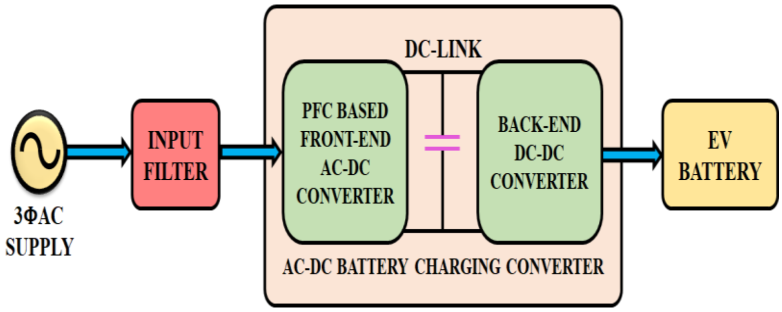


Figure 2.EV Power Configuration of a Battery Charger system

Similarly, in [9] an optimum charging strategy is suggested for EV charging in DS and in this an online optimal charging issue is assigned as the initial one and then using that total system energy cost is reduced with respect to the short term predictive models. Moreover, for solving the optimization issues per concernscorresponding to EV uncertainties, economic interests and data privacy, a distributed novel MPC relied technique is proposed. Likewise, in [10], to achieve better improvements in RES, microgrids and smart grid based EVs, a LAN (Local Area Network) or IoT (Internet of Things) is employed and the IoT highly assists in effective data gathering, as well as utilization, which further helps in better energy management. In this paper, an analyzation is carried out amid the different techniques used in enhancing the performance of PV fed grid tied EV system, in order to identify the optimal technique.

2. Recent Dc-Dc Converter Topologies For Ev Charging Station

The depletion of fossil fuels, as well as the climatic conditions, lead to the vast growth of Electric Vehicles. The EVs battery chargers, normally employs isolated DC-DC converters, which acts as an interface amid the DC-link voltage and the output of Power Factor Correction stage and the Energy Storage Unit. There are many different types of DC-DC converter topologies and the DC-DC converters plays a significant role in increasing the output of RESs.Moreover, when it comes to charging and discharging EVs, the Bi-directional DC-DC converter is the most popular option.These converters are sub-divided into isolated and non-isolated converters. The EV chargers are mainly designed based on the IEC standards, such that the converters performs the charging operation within a short duration of time. The charging levels as per the IEC Standards are demonstrated in Table 1.

Table 1. IEC Standards

CHARGING LEVELS OF EV STATIONS International Electro–technical Commission (IEC)		
AC Charging Level-1	AC/DC Charging Level-2	DC Fast Charging Level-3
Voltage 120V. 1 Phase AC	Voltage 208V or 240V. 1 Phase AC	Voltage 208V or 240V. 1 Phase AC
Amps 12-16 Amp	Amps 20-25 Amp	Amps 12-16 amp
Charging Loads 1.5 kW	Charging Loads 2.5 kW to 10 kW	Charging Loads <90 kW
Charge time for Vehicle 5-8 km of per hour charging	Charge time for Vehicle 10-20 km of per hour charging	Charge time for Vehicle 80% charge in 20-30 min

Moreover, the battery involved has to assist the charging operation, which takes place in a specified configuration. Hence, a novel ICFBDC (Isolated Current Fed Bi-directional DC-DC) converter is developed for Reconfigurable Split Battery (RSB) charging for EV application. The defined converter highly assists in decreasing the current, as well as the voltage stressacross the switches, also provides wide operating range, simple switching operation and improved voltage gain. The proposed converter involves three stage voltage gain circuit, in order to equalise the two DC voltage levels and functions in two different modes for charging, as well as discharging.

In case of charging, due to increased potential difference, the converter injects high current. While, in discharging mode, the converter provides better voltage gain and thereby discharges the batteries.For ensuring ZVS operation, the switching frequency has to be higher than that of the resonant frequency, but due to this a circulating current induces in the converter, which becomes a drawback [11].

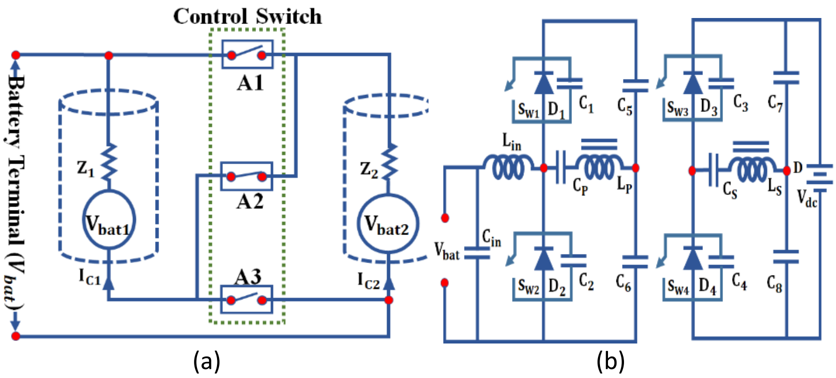


Figure 3.Arrangement of batteries in (a) series and (b) parallel connection

Hence, to reduce the circulating losses, also to offer high energy efficiency and power density, in [12], a Hull bridge CLLC (HBCLLC) converter is introduced and its performance is analogized with other converters like Full Bridge CLLC (FBCLLC) and DAB. In case of Bi-directional charging, normally the converters like CLLC (Two capacitors and two inductors) and DAB (Dual Active Bridge) are employed. Figure 4 illustrates the circuit configuration of FBCLLC and HBCLLC converter.

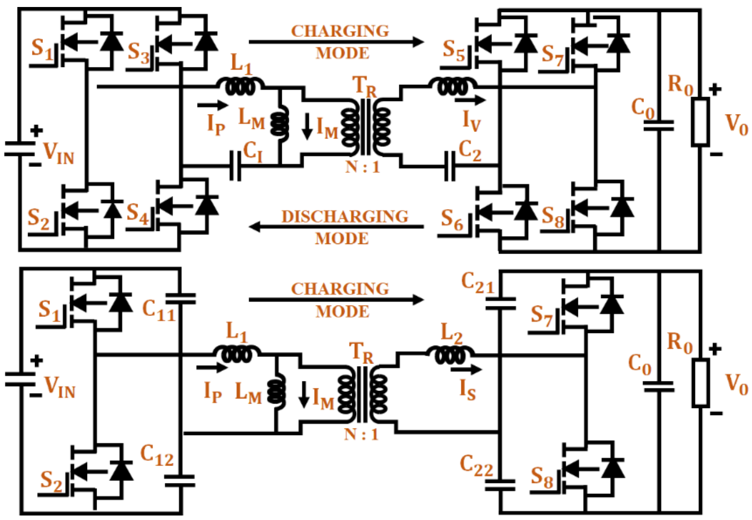


Figure 4. Circuit configuration of a) FBCLLC and b) HBCLLC

In case of full load range, the HBCLLC produces better soft switching characteristics, since input voltage is adjustable. Moreover, it is possible to operate the HBCLLC at resonant frequency, thereby produces increased efficiency and it offers increased power density and relatively low cost. Besides, in case of bi-directional EV charging systems, the HBCLLC converter performs better compared to other converters. Even though, the HBCLLC incorporates cost-effectiveness, reduced cost and size, it exhibits high stress at certain conditions. Hence, in [13] for reducing the voltage stress and to attain increased voltage gain, a novel switched capacitor based bi-directional DC-DC (SCBDC) converter is developed for EV charging.

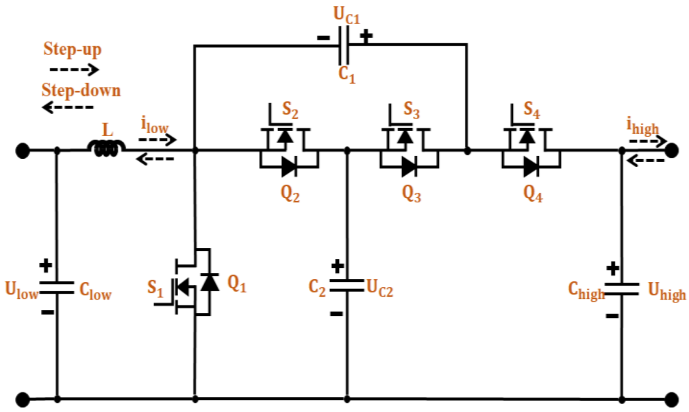


Figure 5.DC-DC Novel Switched Capacitor Bi-directional converter

The defined converter offers step up/step down voltage gain essential for EVs. Moreover, the synchronous rectifier involved offers zero voltage switching, excluding any additional hardware. Figure 5 depicts the defined switched capacitor bi-directional DC-DC converter. The defined converter integrates the reduced voltage super capacitor with the high voltage DC bus, thereby assists in absorbing or giving out the power variationsproduced due to the step change in load.

The proposed converter fulfils the necessities to overcome the difficult dynamic response and also prevents the battery from bringing a step change in current, however, there is no better reduction in the conduction and switching losses. Besides, in [14], a transformerless converter that exhibits reduced losses, improved voltage gain, less voltage stress and reduced component count is presented. Figure 6 illustrates the defined BBC converter.

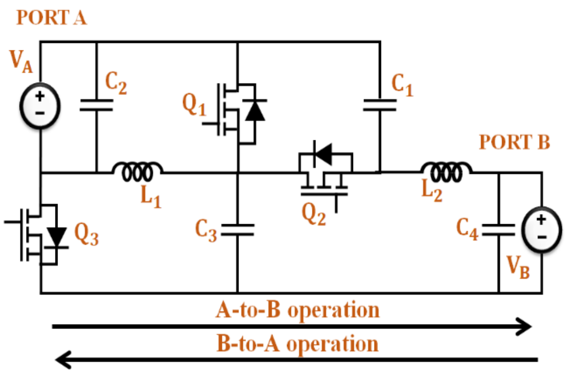


Figure 6. General representation of BBB converter

As synchronous rectifiers involved turns On and Off with respect to the ZVS, Synchronous rectification is employed for enhancing the converter efficiency.Moreover, better steady state, as well as dynamic performance is attained with the proposed converter. However, in real time applications, the switching operations has to be carried out softly, which further aids the reference voltage to attain the desired level. Besides, the fast switching time of MOSFET switch in [15] helps in decreasing the switching losses. In this case, isolated DC-DC converter performance is carried out bya LLC resonant converter and a Pulse Width Modulated (PWM) buck converter functions as the non-isolated DC-DC converter. Figure 7 shows the proposed converter topology.

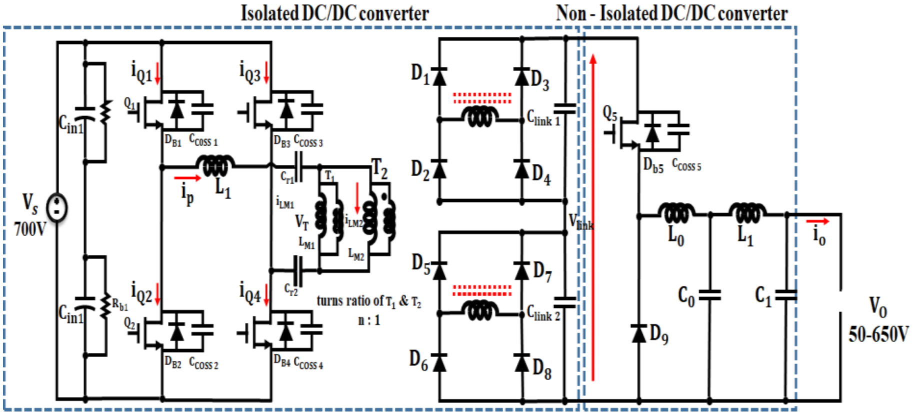


Figure 7.DC-DC converter topology

In order to attain increased efficiency, all over the voltage and load ranges, the LLC resonant converter functions within a fixed switching frequency range, which is equivalent to the resonant frequency, fulfilling the following equation.

$$f_0 = \frac{1}{2\pi\sqrt{L_r C_r}} = f_{SW@LLC} = 120 \times 10^3 [Hz] \quad (1)$$

In which, $L_r$and $C_r$specifies the resonant inductance and Capacitance, which involves the external, as well as the leakage inductances T_1andT_2. Moreover, the buck converter involved is made to function at the CCM mode and the ripple components existing in the inductor current is represented as,

$$\Delta I \simeq \frac{V_{O(max)}}{L_O}\left(1 - \frac{V_{O(max)}}{V_{Link}}\right)T_{S@buck} \quad (2)$$

To foreshow the significance of the proposed work, a prototype is modelled using a 20 kW prototype and the results conclude that it is highly feasible for EV charging application. Still there is necessity for enhancement in the overall efficiency.

2.1.Comparative Analyzation for different DC-DC Converters

An analyzation is carried out amid the various DC-DC converters employed for EV application, in order to identify the significance and is illustrated in Table 2.

Table 2. Analogization between DC-DC converters

Sl. No	METHODOLOGY	REFERENCE	ADVANTAGES	LIMITATIONS
1.	A hybrid DC-DC converter that includes FB and SRT converter for EV charging is proposed.	[16]	• Power variations during charging is solved. • High converter gain and improved Efficiency.	• Proper design procedure is necessary for attaining resonant frequency.
2.	In the proposed paper work, a high power density, as well as high efficiency, On-board Low voltage converter is developed, which involves three phase interleaved LDC converter for offeringthe load current, which further reduces the current	[17]	• Switching losses are decreased significantly. • Precise load current sharing is achieved.	• In real time implementation, the highest maximum current tested is 260A and this is because of the constraints in

	stress.			the electronic loads.
3.	In this paper, a novel Zero Voltage and Zero Switching Full Bridge converter is proposed, for mitigating the power conversion losses.	[18]	• Decreases the switching, as well as the conduction losses. • Necessity for Auxiliary inductance reduces.	• However, the size of the inductance used is large.
4.	A dual port inverter with internal DC-DC transformation system, is defined in this work, so as to alter the DC-link voltage functioning in EVs.	[19]	• Provides efficient power flow directly from the battery to inverter. • Produces un-distorted current.	• The power rating of the DC-DC conversion stage is decreased only for about 12%, in comparison with traditional two stage converters. •
5.	A basis to choose the multiphase interleaved converter topology is defined in this work for improved power, as well as on-board DC-DC converters.	[20]	• Higher performance inductors used provides increased power densities.	• By extending the interleaving topologies, it is possible to apply the proposed work for attaining different power densities.

Figure 8 illustrates the voltage gain analogization amid different DC-DC converters namely LDC, ICFBDC, HBCLLC, SCBDC and BBC, the ICFBDC and the corresponding voltage gain values are given in Table 3.

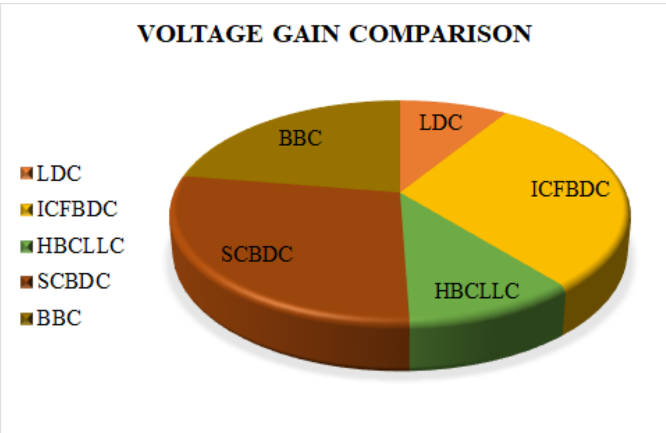


Figure 8.Voltage gain comparison between different DC-DC converters

Table 3. Voltage gain Comparison

Sl. No	DC-DC Converters	Voltage Gain
1.	LDC	2.4
2.	ICFBDC	8
3.	HBCLLC	2.8
4.	SCBDC	7.5
5.	BBC	6

From the analogization, it is identified that among the different converters like LDC [17], ICFBDC [11], HBCLLC [12], SCBDC [13] and BBC [14], the ICFBDC has a high voltage gain of 1:8, compared to other converters.

3. ANALYZATION OF DIFFERENTCONTROL TECHNIQUES USED IN EV CHARGING STATION

The On-board Bidirectional EV chargers are mainly employed for attaining fast dynamic response at the time of charging. The power transfer amid the either sides, highly depends on the architecture of the converter, decrease in passive filtering components and switching losses. Normally, an interleaved phase shifted bridgeless converter is widely preferred for power conversion, since it possess less switching losses and passive filter components. However, there exists complexities in attaining zero voltage switching. Moreover, computing the closer-zero crossing detection and grid frequency estimation at the time of abnormal grid conditions, are found to be the main challenges in the converter topology. The distorted utility voltage existing in the PCC is expressed as,

$V_s(t) = V_{off} + \sum_{n=1}^{2k+1} V_{sn} \sin(n\omega_0 t + \varphi_n)$, for k=0, 1, 2… (3)

Here, the DC offset once after the measurement is denoted by V_{off} and the Phase error is represented byφ_n. Further, to decrease the error amid the assessed and the observed voltage, the reference tracking objective is formulated and given by,

$Objective V_s(t) \rightarrow \hat{v}_s(t)$, where $e(t) = v(t) - \hat{v}_s(t)$ (4)

Then, in consideration with the measurement delay, a first order transfer function is framed. Therefore, in the proposed work, an Adaptive grid-frequency detection method that incorporates noise uncertainty is described, so as to identify the nearby phase reversal occurrences.The results attained from the investigation proves that the THD profiles and the performances at different levels, exhibit the capability of the proposed controller in case of distorted grid conditions that involves continuous error removal. However, the proposed interleaved phase shifted charging technique suits only for the on board configurations and for the off boardconfiguration [21].Besides, in [22] a hybrid energy storage system that involves a SC (Super capacitor) bank and a battery pack, is gaining importance nowadays. Here, for achieving active regulation of energy storage, a Novel Modular Reconfigurable Multi-Source Inverter (MSI) is employed. Compared to other conventional techniques that employs massive high power converters, in addition to bulk magnetic elements, so as to associate battery packs and SC banks, the defined technique possess magnetic less structure.

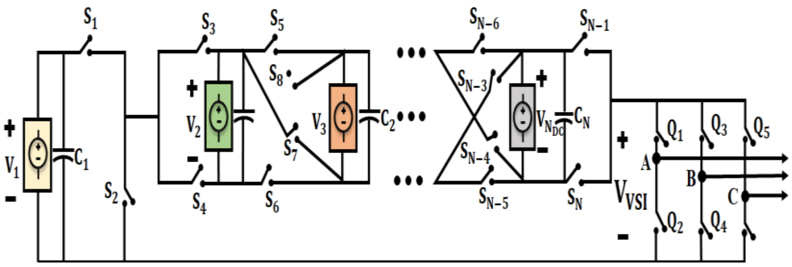


Figure 9. Proposed MSI Structure

Due to this the total weight, as well as the volume of power electronic interface gets reduced, leading to better regulation. For regulating the functioning of SC bank and to regulate the switching actions, a SVM (Space Vector Modulation) technique, along with deterministic SoC controller are presented. Figure 9 illustrates the design of proposed MSI and is considered to be better, with respect to the modularity features and IGBT switches. The lower the switch count, lower is the manufacturing cost and the control complexity. Nevertheless, improved techniques has to be employed for enhancing the performance of the system.Therefore, in [23], an interval type 2, Fuzzy logic controlled Shunt converter that is coupled with high quality charging method is developed for EV applications. In the proposed technique, a bi-directional front end AC-DC PWM converter, 3 phase- 3 wire static compensator and a back end PWM converter are involved.Figure 10 depicts the High quality EVCS.

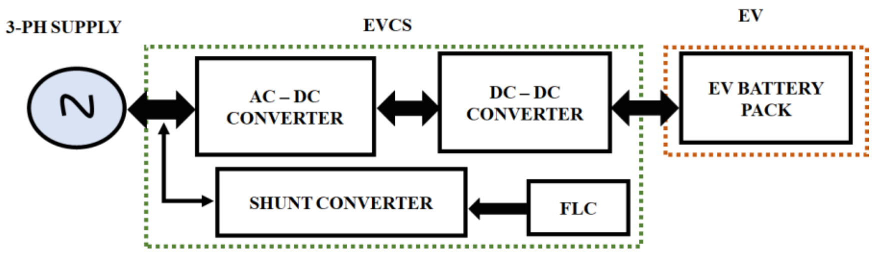


Figure 10.General circuit of High quality EVCS

The defined AC-DC converter employs the combination of DC-link voltage control, along with decoupled current control strategy. Besides, the DC-DC converter uses a multi-step constant current control strategy, so as to perform the charging and discharging function. The expression for DC output voltage of converter is given by,

$$V_{dc} = \frac{2\sqrt{2}V_{L-L}}{\sqrt{3m}} \quad (5)$$

In which, V_{L-L} signifies the line voltage and m signifies the modulation index. The shunt converter involved employs a Fuzzy logic controller assisted instantaneous reactive power theory. The response produced by the defined converter is better than the conventional ones, but issues persists due to the uncertainties and non-linearity's existing in RES.

3.1.Comparative Analysis

The comparative investigation carried out for the different control techniques used in EV charging station are illustrated in Table 4.

Table 4. Comparative analysis for different EV control techniques.

REFERENCE NO.	METHODOLOGY	AUTHOR & YEAR	ADVANTAGES	LIMITATIONS
Ref [24]	In the proposed work, a bi-directional DC-DC voltage quadrupler interleaved converter (VQHBC) is defined for offering wide voltage conversion range and this involves a capacitive voltage divider stage.	Hadi Moradiizkoohi et al. (2020)	• The filter size is low and has high power density. • Built-in equal current sharing is achieved.	• Needs enhancement in the soft switching performance.
Ref [25]	A solar EV charger that possess bi-directional power flow for real and reactive power is proposed and the maximum power from PV system is obtained using a Voltage Source converter.	Anjeet Verma at al. (2018)	• Helps in exchanging the reactive power with the grid. • By injecting the battery power to grid, the technique earns better revenue.	• Necessitates high gain converters to improve the voltage gain.
Ref [26]	In this work, a novel LV2C (Low Voltage-to-cell) battery balancing circuit, which employs battery as the main source for EV application is proposed.	Christina Riczu et al. (2021)	• Better balancing is attained at the time of driving. • Improved range extension is achieved.	• The results differs with respect to the cell aging profile.

Figure 11 depicts the Efficiency comparison amid the different control techniques like VQHBC [24], LV2C [26] and MSI [22] used in EV charging.

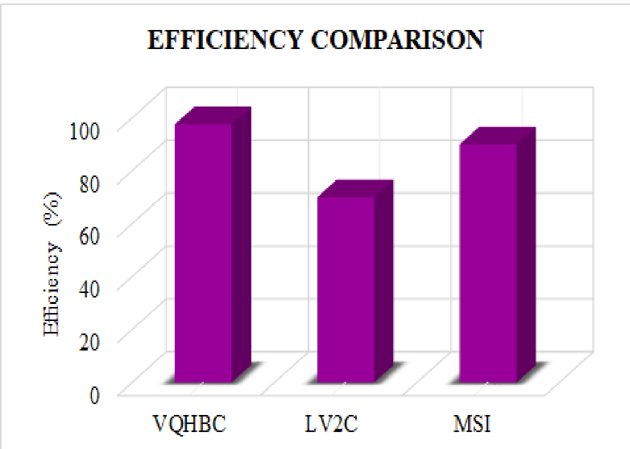


Figure 11. Efficiency Comparison

The Efficiency comparison between various control techniques namely VQHBC, LV2C and MSI, concludes that the VQHBC control technique performs better and possess an Efficiency of 97.6% compared to other techniques like LV2C and MSI.

4. Investigation About Soc Of Batteries In Charging Methodologies Used For Ev Application

The shortage in fossil fuels led to the use of EVs, which faces many challenges, for fulfilling the customer demands. Attaining a fast charging rate of 80 to 120kW using electrical grid power supply, involves high tariff, resulting in increased operating cost. Moreover, only specific contemporary grid has the capacity to manage the higher power demands. Therefore, in [27], a fast charging process is proposed, for reducing the energy consumption, which further enhances the performance of the system. For enhancing the performance of the charging system, a Cuckoo Optimization Algorithm (COA) is employed. Using two main strategies namely HT (Hierarchical Technique) and CRT (Conditional Random Technique), the COA is used and the COA involves a novel transient model for computing the parameters. Figure 12 depicts the configuration used for charging lithium-polymer battery.

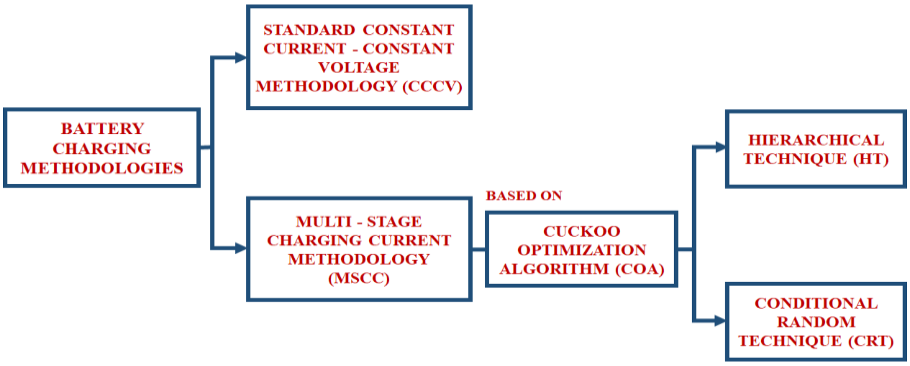
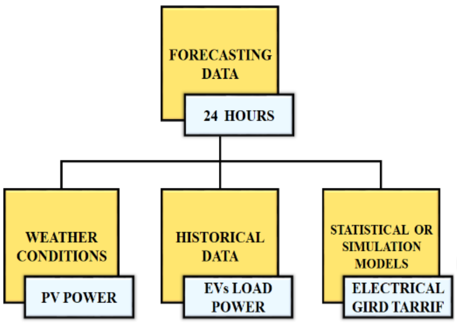
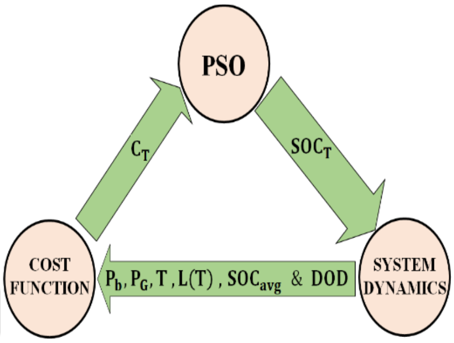


Figure 12.Configuration used for charging lithium-polymer battery

The proposed model involves, OCV that denotes the open circuit voltage and it completely depends on the SoC of the battery. This mainly helps in measuring the voltage necessary to maintain the SoC level, however, the current regeneration time depends on the weight of energy loss. Therefore, energy storage devices are included with the PV system, for achieving continuous power supply. Moreover, this combination assists in better power flow management, at different time intervals and this is well performed using a novel charging technique, which reduce the battery degradation cost, as well as the provides better dynamic grid tariff. Figure 13 (a) illustrates the block diagram for Forecasting and Figure 13 (b) shows the Running cost optimization using PSO.



(a)



(b)

Figure 13. (a) Block diagram for Forecasting and (b) Running cost optimization using PSO

In the defined work, a technique that incorporates battery degradation cost model is introduced and it takes into account the temperature and SoC of the battery. The Particle Swarm Optimization (PSO) technique is employed as an Offline Predictive Optimization tool, for setting the SoC limit of battery based on the PV system, load forecast and dynamic grid prices. In addition to this, a DP (Dynamic Programming) technique is introduced for managing the power flow of the system at lower level and at short interval of time. Figure 13 (a) illustrates the block diagram for the forecasted data and the PSO which helps in decreasing the running cost is depicted in Figure 13 (b). The use of DP improves the efficiency, as well as calculational time of the system. Moreover, when the computed data varies from the forecasted data, the DP aids in compensating the error condition, but necessitates improved techniques for improving the stability of the system [28].

Hence, in [29] for enhancing the stability of the system, thereby to improve the degradation cost and the electricity cost, a (SCAC) suboptimal charging algorithm with certain specific constraints are proposed and its performance highly relies on the Lyapunov optimization algorithm, so as to identify the trade-off amid the user dissatisfaction and the total cost. Normally, every single EVs are allocated to a particular charging station, for smart charging and the constraints involvedare expressed as,

$$\sum_{f \epsilon S} x_k^f(t) = 1, \forall k \epsilon K \quad (6)$$

Then, from the initial point, the constraint 2 of the interval is revised and is expressed as given below.

$$\sum_{s=t_{-k}}^{t-1} (1 - x_k^f(s)) \geq \frac{m_{-k}}{1-\eta_k} x_k^f(t), \forall\ k \epsilon K \quad (7)$$

Further, assume the constraints that possess the inequality, which is stated below.

$$m_k^f \leq \sum_{t=1}^{D} x_k^f\,(t) \leq D, \forall\ k \epsilon K \quad (8)$$

In which, D represents the deadline provided to the time horizon. Moreover, the discharging profit, as well as the electricity cost is expressed as,

$$\Delta C_e(t) = p(t)b(t) - p_d(t)b_d(t) \quad (9)$$

Here, the charging amount, as well as the discharging amount included in the charging station is expressed by, $b(t)$and$b_d(t)$. Further, to attain global charging schedule, a criterion from the SCAC is used to develop a Charging Scheduling Reinforcement learning (CSRL) algorithm and is highly significant compared to RL.

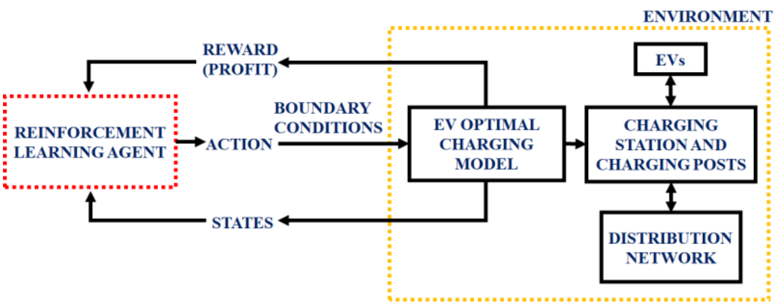


Figure 14.EV charging control system using Reinforcement Learning

Nevertheless, more efficient techniques has to be used for reducing the battery degradation. An optimal charging strategy, which is introduced in [30], brings a novel solution for the improper charging techniques that leads to battery degradation. The defined method, fulfils all the physical constraints involved, also offers better solution for maximizing the benefits of EV system.

In consideration with the uncertainties included in EV charging, the uncertainties of the time series are characterized by the defined techniquewith the development ofa MDP (Markov Decision Process) model. Moreover, the impacts of uncertainties occurring inthe charging strategy are evaluated with the aid of a technique known as Deep Deterministic policy gradient and is based on

Reinforcement learning technique. Figure 14 depicts the EV charging technique with the Reinforcement Learning. Using the proposed technique, high voltage security is achieved, furthermore the temporal correlations involved are also taken into account. However, the proposed technique possess increased computational complexity, compared to the conventional techniques and this is due to that the defined Reinforcement Learning involves nearly 50 to 200 iterations, which is highly time consuming.

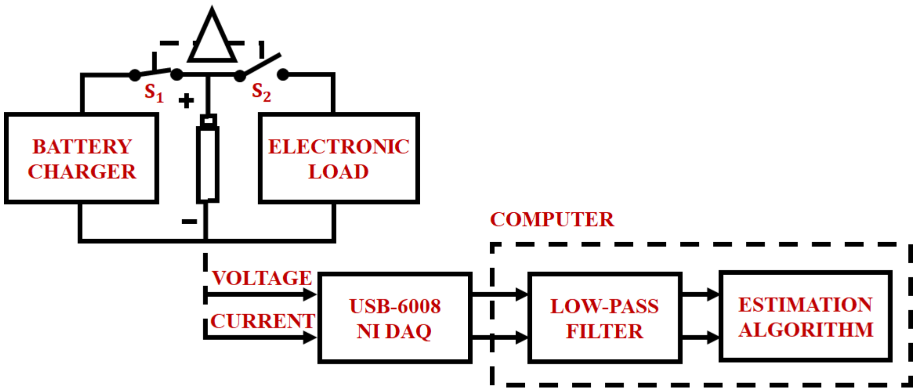


Figure 15. Experimental setup involved in the proposed work

Therefore in [33], a DDRN (Dynamically Driven Recurrent Networks) for EV application is defined in this work. In order to compute both the SoC and SoH (State of Health) of the battery, a NARX (Non-Linear Autoregressive Exogenous) Input architecture corresponding to the DDRN is proposed in this work. Compared to other techniques, the estimation topology when associated with global feedback theorem, enhances the robustness and computational intelligence. The defined technique does not necessitates any of the informations related to the battery parameters, but requires ambient temperature, charging and discharging currents and battery voltage, so as to compute the SoH and SoC of the battery.

Here, an experimental investigation is carried out amid different batteries like LTO (Lithium Titanate) and LiFePO4 (Lithium Iron Phosphate) and the charging, as well as their discharging profiles with respect to different temperatures are measured. Only using the batteries current, temperature and the current, Figure 15 experimental setup used in the proposed work. Using the defined work, better balance is attained amid the Accuracy and Complexity. Moreover, the robustness and the simplicity of the proposed technique makes it well suitable for EV application, thereby decreases the computational burden and the estimation speed. However, care has to be taken for handling the dynamic informations. Normally, the Extended Kalman Filter (EKF) based technique is employed for estimating the SoC of the battery, but has limitations innoise measurement and in the statistics of noise process. Therefore, in [35] a novel SoC estimation model called Adaptive equivalent circuit model is defined.

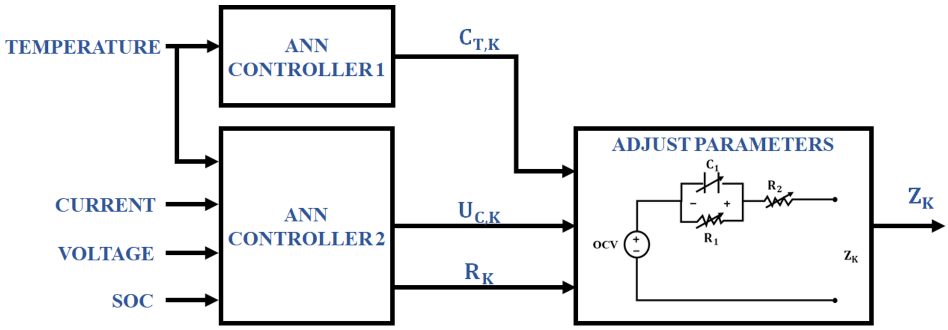


Figure 16.Adaptive ANN-regulated RC model

In the definedmethod, a common cell model whichincorporates the adaptive parameters tracking features is developed and is implemented with the aid of an ANN (Artificial Neural Network) controller. Figure 16 represents the use of ANN controller in RC model and the ANN regulated RC model equations are given in Table 5.

Table 5. ANN regulated RC model equations

Sl. No	**MODEL VOLTAGE (z_k), V**	$\boldsymbol{z_k = OCV\ (SoC_k) + R_k i_k + u_{c,k}}$
1.	SoC (%)	$SoC_k = \frac{C_k}{C_n} \times 100\%$
2.	RC network voltage ($u_{c,k}$), V	$u_{c,k} = u_{c,k-1} e^{\frac{T_s}{R_f C_f}} + R_f i_{k-1} \left(1 - e^{\frac{T_s}{R_f C_f}}\right)$

In the above table, the R, R_f and C_f represents the model parameters, which are considered to be the non-linear functions corresponding to input variables. For attaining better SoC estimation and quick convergence speed, a UKM (Unscented Kalman Filter) is employed and is a variant of EKF. Further, for achieving the process noise covariance of the statistics, the normal UKF employs unscented transform. Then for computing the measurement noise covariance, an ALS (Autocovariance Least Squares) method is used, which further improves the Estimation accuracy.Nevertheless, there is no proper technique for enhancing the battery model accuracy with respect to various temperatures, as well as ageing conditions.

4.1. Comparative Analyzation

Many different methodologies employed for powering PV fed grid tied EV charging station were considered and an analogization is carried out between them. Table 6 shows the Comparative analysis of different battery regulation techniques used in EV charging.

Table 6. Comparison between Battery Analogization techniques

REFERENCE NO.	**METHODOLOGY**	**AUTHOR & YEAR**	**ADVANTAGES**	**LIMITATIONS**
Ref [31]	Advanced Battery modelling, along with Multi objective constrained non-linear optimization method is employed in this paper, for analysing the appropriate charge estimation of the battery.	Kailong Liu et al. (2018)	• Provides feasible health conscious charging with necessary trade-offs. • Gives out better energy conversion efficiency.	• Validation of the proposed work is not taken into consideration.
Ref [32]	In this work, a polynomial fit belonged to a higher order that includes state dependent co-efficients for the SoC range is proposed.	Benedikt Haus et al. (2019)	• Accurate estimation is achieved. • Better EKF convergence is attained.	• However, the yield attained is not satisfactory.
Ref [34]	Star Structured Switched	Yunlong Shang et	• The defined	• Involves

	capacitor Equalizers connected in series is introduced in this work for attaining better efficiency and balancing speed.	al. (2017)	technique offers fast speed, simple modularization, improved efficiency and reduced cost.	high inrush current due to zero initial voltage of the capacitor.
Ref [36]	To choose the optimal statistical feature subset,a novel feature selection technique is employed. Moreover, RNN-LSTM (Long Short Term Memory) is employed for estimating the batteries life time.	Benvolence chinmona et al. (2020)	• Improved Capacitor prediction accuracy is attained. • Decreases the count of inputs and the total amount of processing data.	• Necessitates more corresponding data to decide robust feature selection.
Ref [37]	In addition to the RNN-LSTM, a Rolling learning technique is proposed. Then for computing the SoC of the battery, an improved Square root Cubature KM along with Multi-innovation technique is proposed.	Xin Shu et al. (2020)	• Quickly converges with the reference value. • Precisely computes the characteristics of the battery.	• Suits only to satisfy the online necessities.
Ref [38]	RNN-LSTM is defined in this work for computing the battery' SoCs based on the current, voltage and temperature straight the way from the battery SoC and also to encode dependencies with respect to time.	Ephrem Chemali et al. (2017)	• Has the capability to learn by their own. • Sustains better estimation accuracy with respect to different ambient temperatures.	• However, in case of different batteries, the architecture of the proposed technique varies.
Ref [39]	A Unified Methodology that incorporates RNN along with DFS (Deep Feature Selection) is defined in this work for the battery modelling.	Ruxiu Zhao et al. (2018)	• The defined current input model attains precise dynamic response forecasting beneath different temperature conditions.	• Power input model has to be employed for future battery management system.
Ref [40]	An energetic model with a sub-model named multi-physical model is proposed in this work for decreasing the Total cost of the Ownership (TCO).	Anthony Babin et al. (2017)	• Without using any intelligent recharge topology, the proposed technique gives out better results.	• However, the TCO highly relies on the ageing and the battery price.

The comparison amid algorithms that are used in estimating the SoC of the battery are illustrated in Table 7 and the comparative chart corresponding to it is illustrated in Figure 17.

Table 7.Comparison between Algorithms used for EV charging

Sl.No	ALGORITHMS	SOC%	
		MAE	RMSE
1.	SRCKF	0.91	0.92
2.	LSTM	0.774	1.10
3.	DDRN	0.625	0.7012
4.	MC-LSTM	0.9458	0.1024
5.	DFS-RNN	0.029	0.037

The comparative analysis is performed is carried out amid different techniques like SRCKF [37], LSTM [38], DDRN [33], MC-LSTM [36] and DFS-RNN [39], forestimating the SoC of battery efficiently and within a short period of time.

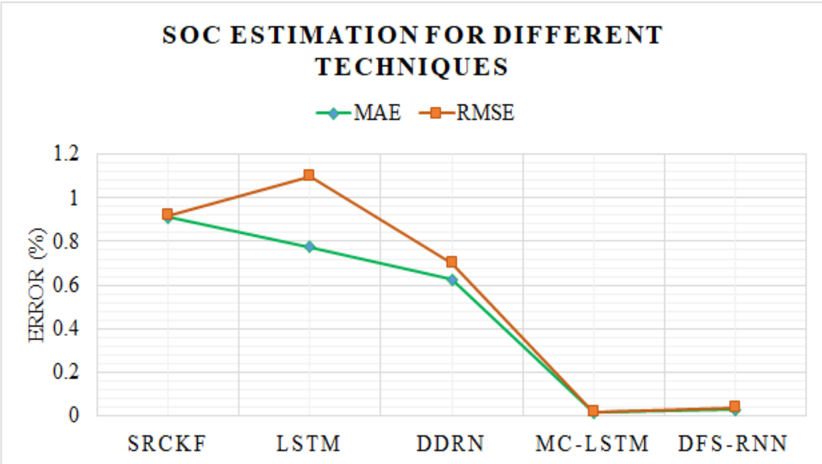


Figure 17. SoC Estimation for different techniques

From the analogization, it is concluded that the MC-LSTM possess less MAE and RMSE compared to other techniques like SRCKF, LSTM, DDRN, MC-LSTM and DFS-RNN, which further enhances the Accuracy of battery,also improves the SoC estimation.

5. Conclusion

The integration of RES in distribution network and the introduction of EVs in automobile industry have brought vast changes in the economy of many developing countries. In order to electrify the transport sector effectively and with high reliability, the EVs has to be charged with the aid of Power electronic converters. For reducing the gasoline consumption and to improve the range of battery capacity, many novelties has been performed in the development of Power Electronic converters.As, these convertersacts as the main interface amid the EV charging system and the power network, novel advanced and reliable converters has to used. Therefore, in this paper an analysis is carried out regarding the different power electronic converters employed in EV charging. Moreover, the advanced control techniques used in the regulation of power electronic converters are also investigated in this work. In addition, a comparative analysis is performed amid the various DC-DC converters and the control topologies employed in the energy management of the charging system. From the analogization, it is concluded that the DC-DC ICFBDC possess a voltage gain of 1:8 than other converters like LDC, HBCLLC, SCBDC and BBC. Besides, the VQHBC control technique brings out an Efficiency of 97.6%, compared to other techniques like LV2C and MSI. Moreover, the results achieved from the comparison of Algorithms used in EV charging, informs that the MC-LSTM algorithm gives out reduced MAE and RMSE, which further enhances the overall efficiency of the system.In future works, the adoption of advanced DC-DC converters and improved control approaches greatly aids in enhancing the Voltage gain, energy management and overall efficiency of the EV charging system.

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