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# Optimization and Control Techniques for Electric Vehicles

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**ABSTRACT:** Electric vehicles (EV) are developed to overcome the energy crisis and environmental crisis caused by conventional vehicles. To improve the efficiency of electric vehicle, the important aspect to be improved is battery performance in electric vehicle. EV consists of power electronic circuits, since the inverter and converters used in EVs are nonlinear devices, harmonics are produced. These harmonics affects the efficiency of EV charger circuit. This paper gives a technical review about effects of harmonics on battery charging. The onboard EV charger circuit mainly consists of filters, power converters and battery. The performances of different filters are stated, similarly different power converter topologies. PWM (Pulse Width Modulation) technique is the heart of power converter, over the years PWM techniques has gone through much improvisation. The review focuses on Optimization techniques which play a vital role in determining the optimal solution. The optimization technique when combined with PWM techniques provides better mathematical solution. The technical review focuses on mitigating the harmonics by analysing the performance of filters, power converter topologies, PWM techniques and optimization techniques

**KEYWORDS:** Electric vehicle, Harmonics, Battery, Nonlinear devices, Filters, Power Converters.

## I. INTRODUCTION

Electric vehicles are rapidly gaining importance in recent years. The major contribution to air pollution is by conventional vehicles [1].  $\text{CO}_2$  is a greenhouse gas which is a major contributor for global warming, the major contributor for greenhouse gases are conventional vehicle [2]. In order to promote the EVs adoption, subsidies are provided in various forms such as rebates, sales tax exemptions, and tax credits [3]. Infrastructure construction policies and production policies promotes the adoption of electric vehicle, penetration of electric vehicles into market can go up to 70% [4]. Significant advantage of EV is that compared conventional vehicle, EVs does not produce any soot [5] and noise [6]. EV market is growing and expected to reach 3.8 billion by 2020 [7]. A comparative study was carried out for conventional model vs electrified model to study the CHG emission. Simulation was done considering the driving pattern during real time traffic. The study revealed there are several policies to support EV adoption to achieve lower CHG emission [8]. A study was carried out across 50 states in USA, to analyse the energy and carbon footprint for EV, conventional and hybrid vehicle. The study revealed, EV was best option in 24 states, since it emits least carbon [9], as per the analysis for city routes, electronic vehicles are efficient [10]. The sale of electric vehicle has increased by 92% which means 765,000 units was sold till mid-2019, compared to 397,000 units sold in 2018.[11] in 2017, the oil consumption for transportation purpose is 60%. Henceforth there is a need for alternative such as EV [12]. Some country government such as France, England, Germany have announced Internal combustion engine will be banned in future. [13]. in India, transportation sector contributes about 10% of air pollution [14]. For Ghana's energy mix scenario,  $\text{CO}_2$  emission by conventional vehicle is 3.35 times compared to electric vehicles [15]. Road transportation in European Union accounted for 82% of  $\text{CO}_2$  emission and 18% greenhouse gas emission [16]. The exhaust emissions of conventional vehicle contains pollutants namely Nitrogen Oxide ( $\text{NO}_x$ ) in the form of Nitric Oxide (NO), Carbon dioxide ( $\text{CO}_2$ ), Carbon Monoxide (CO), Nitrogen dioxide ( $\text{NO}_2$ ), Hydrocarbons, Sulphur oxides (SOX) in forms of Sulphur dioxide ( $\text{SO}_2$ ), particulate matter (PM10) [17]. Pollutants emitted from conventional vehicle effects the vegetation [18]. Roads which has traffic congestion especially by diesel vehicle emits particulate matter. People living in public residence which is near to this roads, leads to asthma development [19]. With the disadvantage of conventional vehicle there is a need for electric vehicle. With the national subsidy available, china adopted 49.3% to 65.07% of electric vehicles [20]. In developed countries, electric vehicles are used for passenger transportation [21].

Due to technical advancement, 62% to 76% of commercial class 2B-7 vehicles can be supported by EVs [22]. To improve the efficiency of EVs for long drive application, the innovation related to inverter, converter and battery technology is boosted [23]. Based on the connection and energy source EVs can be classified into three categories, Plug-in hybrid electric vehicle-PHEV, hybrid electric vehicle-HEV, and battery electric vehicle-BEV. PHEV and HEV consist of a hybrid engine that uses both electrical and internal combustion engines. Battery technology is used as an energy source for BEV and batteries are charged via a charging stations [7,24]. For a human, heart is the significance of life similarly battery has same importance in electric vehicle [25]. The charging time and battery life is greatly influenced by characteristics of battery charger [26]. The charging station is categorised as level 1, level 2 and level 3 by the society of Automotive engineers (SAE) J1772 [27,28,29]. AC/DC charging approach is used to charge the battery under the level 1 and level 2. The voltage level in level 1 and level 2 is 120 and 208/240 V<sub>AC</sub>, respectively. For Level 3, the approach used is high voltage and fast-rate DC Charging Slot [30]. Recharging time of the battery depends on two aspects: 1. Capacity of battery. 2. Charging post power capacity. When EV is connected to charging outlet of home or office, for the battery to fully charge it takes about 6-8 hours [31]. EVs, are manufactured with on board chargers, when the on board charger is connected to public power grid, the battery is charged which is the power source for electric vehicle [32,33]. The on-board charger may be composed of two-stage or single-stage [34] EV consists of power electronic circuit to charge battery as well as to drive a motor, and the high voltage in the circuit, which needs to be chopped to control the driving circuits, as a result it is inevitable to produce high frequency harmonic voltage/current components inside [35]. The power supply obtained by power grid is AC, but it needs to be converted into DC for the battery to charge, this conversion is done by power electronic converters which are basically nonlinear loads. These power converters introduces harmonics, if the harmonics are not rectified the efficiency of converter is greatly impacted [36]. EV chargers evolution began with simple uncontrolled single phase full bridge rectifier, resulting in current harmonic distortions and low power factor [37]. The power electronic converters are basically arrangement of diode, thyristor, IGBT, etc. which are semiconductor switches. The switching devices exhibit higher switching losses reducing the overall efficiency, this loss further is added with harmonics produced by converter [38]. Presence of harmonic components leads to poor power quality of on-board chargers which are commercially available [39]. Due to the fast switching of power electronic devices, battery is under high frequency stress [40]. Topologies of power converters in an EVs affect shape, amplitude and frequency of ripple [41,42,43]. For an on-board chargers, single stage chargers are best suited for tackling the battery current ripples [44,45]. If the ripples of high frequency are not mitigated it may enter the battery system of EV [46]. The harmonics affects the power factor of the grid. The harmonics may cause additional losses and affects the equipment efficiency [47, 48]. Hence mitigating the harmonics is quite crucial

## II. METHODS AND MATERIAL

### 1. Filter

The charging system of electric vehicle includes input filter. Power converter consists of AC-DC converter, DC-DC converter and a DC bus. Filters are first aspect of charging system. The main function of the filter is to eliminate the unwanted frequency from the fundamental input and allow only the required frequency of input signal. The main reason for current harmonics is, when the sinusoidal input is given to nonlinear loads, current harmonics are generated. Every system has its own impedance, when the current harmonics passes through this impedance it leads to voltage harmonics. To mitigate voltage harmonics shunt active LC filters can be used [49]. The function of shunt active filter is to produce equal but opposite compensating current with respect to fundamental input of the filter. The grid harmonics can be eliminated by shunt filters efficiently [50]. Current harmonics affects the power quality. To produce active compensation, Hilbert transform based active power filters are proposed to obtain fundamental component from the input distorted supply [51]. Power semiconductor filters are efficient in eliminating harmonics when compared to traditional filters [52]. The filter which is effective in mitigating both current harmonics and voltage harmonics is active filter. The advantage of active filter is that it can mitigate the harmonics which are below the switching frequency of filter. Maintaining the high power factor and eliminating harmonics is the combined advantage of three phase four wire shunt active power filter [53]. The combine advantage of active and passive filter is present in hybrid filter. Hybrid active filter is helpful in suppressing current harmonics [54]. Less number of analog building blocks is required for wave active filter. To suppress the current harmonics wave active filter can be used [55]. The charging time of topology consisting of AC-DC conversion stage and DC DC stage can be enhanced by adding an extra inductor filter [56]. To smoothen the current curve and voltage curve, inductor and capacitor are used respectively [57]. When the control strategies such as perfect harmonic cancellation and unity power factor for active power filter was successful in reducing the total harmonic distortion to less than 5% as per the IEEE-519 standards [58]. To determine the harmonic current, techniques related to adaptive filtering can be





used. The disadvantage of adaptive filtering is to detect the current harmonics under low signal to noise ratio condition. To overcome the advantage and to detect the current harmonics, Modify variable step size least mean square algorithm is used [59]. To eliminate the use of electrolytic capacitor and to prevent the twice utility frequency ripple, DC hybrid power filter are effective [60]. For reduction of harmonic distortion produced by power converters, shunt active power filter controlled by PID controller and supervised by adaptive neural fuzzy interface system can be implemented [61].

### 1.1 Power Converter Topologies

#### 1.1.1 Ac-Dc Converter

The function of AC-DC converter is to produce DC output for sinusoidal input. If the traditional rectifier is used for AC-DC conversion it leads to harmonics. To mitigate the harmonics, PFC rectifier model can be implemented using the control technique called Critical conduction mode [62]. When the power factor is maintained to unity the voltage harmonics was found to be between 1 % to 2 % [63]. The dual bridge LLC series resonant converter with hybrid filter, reduces the switching losses as the converter operates below the resonance frequency [64]. AC/DC converter with unified control has the advantage of harmonic reduction as it includes adaptive filter to extract the harmonics [65]. Buck-Boost converters are mostly used in EVs, for power factor improvement and total harmonic reduction, hysteresis control for buck-boost converter is suggested along with correction control of power factor [66]. For BEV charger to ensure unity power factor on AC side, Lyapunov based control of single phase AC-DC power converter is proposed [67]. In comparison with two-stage structure for AC/DC conversion, single stage AC/DC structure was proposed. Since single stage AC/DC enables higher efficiency and low cost. TO mitigate the harmonics additional DC/DC converter is added to DC bus [68]. PWM Resonant converter is a good candidate for isolated/bidirectional converter, as it provides good switching characteristics and the main focus is charging optimization [69]. To cancel the harmonics of triplen order, selective harmonic mitigation pulse amplitude modulation is a good candidate [70].

#### 2.2.2 Dc-Dc Converter

The dual active bridge consisting of two active full bridge for DC DC converter has the advantage of zero voltage switching [71]. For ensuring the safety battery charging, dual stage CC-CV charging method is proposed for DC DC converter [72]. Normally buck converter are used on battery side to obtain ripple free current for battery charging under continuous conduction mode [73-75], which is essential for longer life of battery [76]

### 2.3 PWM Techniques

PWM techniques is usually implemented in converters/inverters. Harmonic elimination PWM (HEPWM) has the superior advantage in mitigating the harmonics as it has the advantages such as low switching loss. For the given input, this technique increases the availability of output [77]. the fuzzy logic based PWM control technique for buck converter is effective in minimising the heat by reducing the charging current, higher efficiency in charging, fast recharging [78]. For a single phase PWM rectifier when combined with PI controller, steady state error can be eliminated [79]. Space vector pulse width modulation control technique is proposed for bi-directional DC-DC converter. The advantage of SVPWM is reduced losses in switching and quick dynamic response [80]. To mitigate the harmonics and to obtain the desired fundamental component Selective Harmonic Elimination is effective [81].

### Optimization Techniques

Optimization is defined as finding mathematical solutions to functions which are fluctuating under several conditions; the value of function may maximize or minimize [82]. Metaheuristic methods are gaining more popularity in the recent years as these are the best option for finding optimal solution to the complex problem. Some of the metaheuristic methods are discussed in this section.

#### 2.4.1 Particle Swarm Optimization (PSO)

The exchanging of information among particle through social interaction is the logic involved in Particle swarm optimization algorithm [83]. PSO is nature inspired computational technique, which is similar to the concept of flock of birds and school of fish. Every particle in PSO is given a position and velocity as shown Eq (1) and Eq (2) respectively.

$$Y_i = Y_{i1}, Y_{i2}, Y_{i3}, \dots, Y_{ir}, \quad (1) \quad V_i = V_{i1}, V_{i2}, V_{i3}, \dots, V_{ir} \quad (2)$$



Decision of every particle in PSO is based on the neighbours experience and its own experience. During the iteration process, the best experience of each particle is named as Pbest. Gbest is the global best which can be accessed by any particle. The updated velocity and position is obtained as per the below equation (3) and (4) respectively,

$$V_i^{k+1} = W V_i^k + c_1 r_1 * (P_{best} - Y_i^k) + c_2 r_2 * (G_{best} - Y_i^k) \quad (3)$$

$$Y_i^{k+1} = Y_i^k + v_i^{k+1} \quad (4)$$

ith particle velocity at iteration k, weigh factor of inertia is given as W, coefficients for acceleration is defined as C<sub>1</sub> and C<sub>2</sub>. To represent random numbers between 0 and 1 r<sub>1</sub>, r<sub>2</sub> is used. At iteration k, position of the particle is also defined. The first step being the initialization of particle velocity and position is followed by fitness evaluation of each particle. Based on the experience of each particle, Pbest is decided and Gbest access is given to all the particles. The criterion for the optimization is finding the best position and velocity compared to previous experience and neighbour experience.

2.4.2 Honey bee Optimization

Pham, Ghanbarzadeh et al developed the Bees algorithm in the year 2005 [84]. Bees algorithm imitate the behaviour of honey bees in reproduction and nectar collection [85]. The Fig 2 represents the flowchart of bees algorithm. Since the bee algorithm is a imitation of natural process, the first step is foraging process. To do the foraging process scout bees are used, these scout bees travels different places and find outs the best area containing flower. Scout bees convey the information about the best places to the other bees in the hive through waggle dance. Through waggle dance, scout bees provide information about distance of the best place from hive, food quality and energy required to harvest it. The other bees along with scout bees travel to reach the best place. Information about the level of food harvesting will be provided in the next waggle dance. If the best place is still fit for food source more bees will be sent. The criteria for optimization is, based on the step 6 and 7, best bee will be selected and will be the new representative.

2.4.3 Genetic algorithm

Genetic algorithm was developed by John Holland in the year 1960, based on the concept of Drawin`s theory of evolution. Based on natural selection and genetics, GA performs random search [86,87]. The first step in the process is initialization of population. If the size of the population is large, to select the individuals appropriate techniques can be implemented which is also called as fitness evaluation shown as second step in the flowchart. A part of population will be selected to reproduce the next generation. From the selected population, mating is done randomly to produce the next generation this process is called as crossover. Alteration of one or more gene value in chromosome from its original state is called as mutation. Mutation process deals with maintaining the diversity in genetics from one generation to the next generation. The process of crossover and mutation occurs until the chromosomes of new generation are different from the first generation, which leads to improvement in the fitness of population.

2.4.4 Gravitational search algorithm

Rashedi et al introduced GSA to provide optimization solution based on the law of gravity and motion of mass [88]. According to Newton`s law of gravity, each object attracts the other object due to gravitational force. The gravitational force between is directly proportional to the product of masses and inversely proportional to the square of the distance between them. Due to the force object keep moving, objects with more mass move slowly while the objects with less mass move faster. The objects with more mass are considered as best solution and high fitness. The objects with less mass give worst solution and less fitness. Every object`s current velocity depends on object`s previous velocity and object`s acceleration which is called as law of motion. All the masses in the GSA obey the law of gravity and law of law of motion.

Fig 4 represents the flowchart of GSA. Consider a system with N objects, each object having dimension as `d`, kth object can be defined as

$$X_k = X_k^1, X_k^2, X_k^3, \dots, X_k^n \quad (5)$$

Where k=1,2,3,.....,N

At time the force acting from object k to object h is defined as

$$F_k^d = G(t) \frac{M_{bk}(t) * M_{ak}(t)}{R_{kh}(t) + \epsilon} (X_h^d(t) - X_k^d(t)) \quad (6)$$

M<sub>bk</sub>(t) represents passive gravitational mass for object k at time t. M<sub>ak</sub>(t) represents the active gravitational mass for object h at time t. G(t) represents gravitational constant at time t. R<sub>kh</sub>(t) is the Eucldian distance between object h and k which is calculated as



$$R_{kh}(t) = \sqrt{X_k^2(t) - X_h^2(t)} \quad (7)$$

For time t, the total force acting on object k for dimension d is calculates as follows

$$F_k^d(t) = \sum_{h=1, h \neq k}^N rand_h F_{kh}^d(t) \quad (8)$$

$rand_h$  represent the random number in the interval [0,1].

For time t, acceleration of kth object and for time t+1, velocity of kth object in dimension d is defined as

$$a_k^d(t) = \frac{F_k^d(t)}{M_{kk}(t)} \quad (9)$$

$$V_k^d(k+1) = rand_k * V_k^d(t) + a_k^d(t) \quad (10)$$

$M_{kk}(t)$  is the inertial mass of the kth object, in the interval [0,1].  $rand_k$  is a random number.

$V_k^d$  represents velocity of kth object in dimension d at the time t. with reference to above equation, the position change of each particle is given by

$$X_k^d(t+1) = X_k^d(t) + V_k^d(t+1) \quad (11)$$

For GSA, the objects are considered to be best if the mass is heavier and moving slowly. The gravitational and inertial masses are calculated as

$$M_{bk} = M_{ak} = M_{kk} = M_k \quad (12)$$

$$m_k(t) = \frac{fit_k(t) - worst(t)}{best(t) - worst(t)} \quad (13)$$

$$M_k = \frac{m_k(t)}{\sum_{h=1}^N m_k(t)} \quad (14)$$

Worst(t) and best(t) are calculated as follows

$$best(t) = \min_{k \in \{1, \dots, N\}} fit_k(t) \quad (15)$$

$$worst(t) = \max_{k \in \{1, \dots, N\}} fit_k(t) \quad (16)$$

#### 2.4.5 Satin Bower bird algorithm

Satin bower bird optimization is based on the life of satin bower bird [89]. Male satin bower birds create attractive bowers to attract female satin bower birds. The first step in optimization process is defining the positions to every bower, random initialization is performed to every bower. The factor of probability depends on the attractiveness of the bower, probability is calculated as

$$P_j = \frac{fit_m}{\sum_{n=1}^{mb} fit_i} \quad (17)$$

Fit of the solution is defined by  $fit_m$ , mb defines the number of bower. Fitness is calculated by the eq(18).

$$fit_m = \begin{cases} \frac{1}{1 + f(X_m)} & f(X_m) \geq 0 \\ 1 + |f(X_m)| & f(X_m) < 0 \end{cases} \quad (18)$$

Cost function to be optimised is  $f(X_m)$ . For each iteration of algorithm the change in bird's bower is calculated by below equation



$$X_{mk}^{new} = X_{mk}^{old} + \lambda_l \left( \left( \frac{X_{jl} + X_{elitel}}{2} \right) - X_{mk}^{old} \right) \quad (19)$$

attractiveness of the target bower is determined by  $\lambda_l$  which is defined as

$$\lambda_l = \frac{\alpha}{1 + P_h} \quad (20)$$

Mutation process is applied for changing variables of bower, for average of  $X_{mk}^{old}$  normal distribution is applied and variance is calculated as shown in eq (23).

$$X_{mk}^{new} \square N(X_{mk}^{old}, \sigma^2) \quad (21)$$

$$X_{mk}^{new} = X_{mk}^{old} + (\sigma * N(0,1)) \quad (22)$$

$$\sigma = Z * (V_{max} - V_{min}) \quad (23)$$

Upper limit and lower limit is defined by Vmax and Vmin parameters respectively. Z defines the percentage of difference between upper and lower limit. Algorithm selects the best bower among the old and new bower Yang X S proposed the BAT algorithm in the 2010 based on the echolocation behaviour of bat, used to sense data [90]. Based on the echolocation, bats understand whether it is food or prey or any other barriers. bats fly in random direction with some velocity, adjusts its loudness of echo to sear h the prey. As the prey is approaching the bats adjusts its loudness of echo. The agenda of algorithm is to best region for food in search area [91]. At initial stage BA produces fast convergence which can be considered as the advantage, many techniques are explored to improve the performance of BA [92]. To solve the optimization problems related to real-time, differential evolution algorithm is used. The merits of differential algorithm are ease of implementation, capability to withstand rigorous testing, simplified structure [93]. To calculate switching angle, Newton-Raphason method can be implemented as it can achieve precision and quadratic convergence [94]. To determine the phase angle and amplitude of harmonics and fundamental component, Recursive Least Square algorithm can be used, the merits being simplified computation, convergence and precision [95]. For noisy environment, the adaptive linear neural network and dynamic forgetting factor recursive least square algorithm can perform precise estimation of results [96]. Teaching learning based optimization was introduced [97] based on the concept of teacher on learner. For multilevel inverter to achieve optimal angles of switching for harmonic elimination, Enhanced teaching learning based optimization can be used. [98]. In a distribution system, to estimate the different components of harmonics Hopfield neural network algorithm can be implemented. The algorithm is efficient in providing compensation to issues such as reduction of harmonics correction of power factor and balancing of load, for which appropriate control signal is given to shunt compensator [99]. Takagi sugeno fuzzy control technique provides better compensation for harmonic currents [100]. Issues related to unbalancing and harmonics can be solved efficiently using Improved dead beat algorithm [101]. predictive tuned filter (PTF)-based p-q theory uplifts the fundamental component from the distorted signal. This technique provides improve levels of harmonic compensation [102]. To achieve efficient control sequence for PWM, Improved Immune algorithm is a better candidate as it can achieve reduced total harmonic distortion [103].

### III. RESULTS AND DISCUSSION

With the implementation of active power filter, the THD of the source current is reduced, the power factor is improved to 0.99 [51]. The concept of power semiconductor filter is capable of improving the power factor to 0.999 [52]. The grid current THD was reduced to 1% by using Hybrid active filter [54]. With the implementation of shunt active power filter the THD component of current source profile was reduced to 2.7% with less than the IEEE-519 standards [58]. The output voltage of AC-DC power converter with DC hybrid filter consists of twice utility frequency component, high switching frequency and the ripple content in the output waveform was small [60]. PFC a boost converter topology, 10 V is fixed as reference output voltage, 5 V is fixed as reference input voltage for which the output voltage sensed was 9.9V, due to the diode bridge rectification a drop of 1.5 V was observed. Overall the circuit has good harmony with other circuits and produces negligible error [62]. The dual bridge LLC series resonant converter operating at 420V and 3.57 A, produces an efficiency of 96.22% at the point of constant current to constant voltage transition point [64]. The single phase bidirectional EV charger, consisting of DC/AC converter and interleaved two-leg buck-boost converter was successful in reducing the THD to 2.5% from 65% THD of load current produced by

RLC load and the crest factor was reduced to 1.41 from 1.7 [65]. Hysteresis control technique was implemented to Buck-Boost converter to improve the power factor and THD reduction. The charger circuit was tested for resistive load without the power factor correction, as a result huge amount of current was drawn by the charger leading to efficiency reduction. In the next case the charger was connected with LC filter and appropriate controller, the current drawn by the charger was reduced to half and the input power factor was improved to the highest being 0.99 [66]. The single stage charging structure was implemented with DC active power filter method to mitigate the current harmonics from the grid side, a small DCC/DC converter was used. The single stage charging structure reduced the THD to 1.09% from 6.19% [68]. The SHE technique is capable of completely eliminating the 3<sup>rd</sup>, 5<sup>th</sup>, 7<sup>th</sup> harmonics [49]. The Harmonic elimination strategy (HES)-PSO was implemented to control the 13 level uniform step asymmetrical multilevel inverter, to minimise the harmonics. The HES-PSO technique is effective in cancelling the 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup>, 13<sup>th</sup> harmonics from the output voltage [83]. The Bees algorithm was implemented to eight benchmark functions, out of it one of the function was Rosenbrock's function in two dimension. The Bees algorithm obtained 100% success and evaluation was reduced to half compared to other method such as Genetic algorithm [84]. The SBO-based selective harmonic elimination pulse width modulation technique (SHE-PWM) produces less harmonic content when compared to the fundamental component for 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup> harmonics, when compared to GA based SHE-PWM [89]. To evaluate the performance of GSA, some of the benchmark functions was considered, for which GSA was faster in achieving the global optimum and faster rate of convergence compared to real genetic algorithm and PSO [88]. Hence the performance of filters, power converter topology and optimization techniques is discussed.

#### IV. CONCLUSIONS

The advantage of EVs is it does not emit greenhouse gases, due to this advantage EVs are globally accepted and the rate of acceptance is increasing year by year. Performance of EV can be improved by analysis the effects of harmonics on battery charger circuit, as battery is the vital component of EV. The battery charging circuit consists of filters to reduce the harmonics entering from the grid side, based on the results and discussion, active filter, power semiconductor filter, Hybrid active filter and shunt active filter are effective in reducing the THD. The next aspect of battery charging circuit is power converters topology. PWM resonant converter topology, dual bridge LLC series resonant converter with hybrid filter topology, Buck Boost converter topology is discussed, these are some of the converters which are effective in reducing the THD and enhancing the perform of battery charging circuit. The efficiency of power converter can be improved by optimal switching angle calculation. PWM technique is widely used to calculate the switching angle for power converter. PWM technique is improved over the years, SVPWM technique and SHE technique is discussed. Metaheuristic techniques have gained lot of popularity over the years, SBO, PSO, GA, GSA, HBO techniques are discussed. The performance of the optimization technique depends on many aspects to name a few, load conditions, controllers implemented, PWM techniques. The optimization techniques such as GA, PSO, GSA, HBO, SBO are providing better optimal solutions. Hence, filters, power converter topology, PWM techniques and optimization techniques play avital role in improving the efficiency of EV.

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