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Solar PV based EV charging in India: The growing start-up eco system Analysis, Challenges and solutions

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Abstract

In recent years, the Indian startup ecosystem has exceled and come into its own driven by factors such as enhanced funding, consolidation activities, evolving technology and a burgeoning domestic market. As on August 2020 Country has witnessed a launch of more than 55000 startups with more than 3200 startup raising fund of $63 Bn in last five and half years alone. With an objective of creating employment with be at one's own boss the startup eco system is moving at a good pace. The high percentage of educated youth with good technical background, IT facilities and increased Internet and mobile penetration are the drivers for spreading start up revolution in India. Infrastructure, understanding and implementing startups with government regulations and availability of finance at various stages of growth could be some of the challenges for startups. Electrical vehicles are promising technology for reducing greenhouse gas (GHG) emissions and other environmental impacts for road transport. High import dependence with continuously increasing prices of oil possesses a serious challenge for India's future energy security. In this paper how to implement the solar PV charging station with existing regulatory framework is explained with future challenges. Mathematical modelling with equations to implement the advance control strategy while comparing PI tuning with Genetic Algorithm based tuning technique to implement solar PV based EV charging is an honest attempt made to give very vital information to those who wish to install solar PV charging station at home, complexes, workplaces or willing to do start up or business related to solar PV based charging station installations for Electrical vehicle charging.

Keywords: Mobility mission, standalone, greenhouse gases, sizing, design

INTRODUCTION

Indian automobile industry is fastest growing automobile industry in the world today. By 2020 it is expected that the annual demand for two wheelers, commercial vehicles and passenger vehicles will be 34 million, 2.7 million and 10 million respectively, thereby making India the third largest vehicle market in the world. Increase in vehicle population will result in drastically increase demand in fossil fuels and have an undesirable impact on environment [1]. Indian automotive industry has seen considerable growth in the last two decades mainly due to economic liberalization including 100% FDI in the sector [2].Transportation sector accounts for 30% of worldwide energy consumption and is the 2^{nd} largest source of CO_2 emissions contributing to 20% of global GHG as per international energy agency globally. There will be significant increase in oil demand in near future from countries like China and India. Country largely depends on oil imports to meet its energy needs. Issues related to conventional vehicles are, necessary to mitigate for economic development. National energy security and growth of domestic manufacturing capabilities is the prime agenda of NEMMP 2020.According to the NEMMP (Nations Electric mobility mission plan) India aimed to deploy 400,000 passenger battery electric cars (BEVs) by 2020 [3].While achieving this target, India can avoid importing 120 million barrels of oil and avoid 4 million tons of CO_2 emissions by 2020 based on real-world conditions of use [3-4].

For economic development it is inevitable and crucial to develop technologies those Eliminate adverse effect of conventional automotive technology in India [1]. As the environment concern is raising globally, pollution is major concern in India too. India is fourth largest consumer of energy in world. Much of energy requirements are met by crude oil and coal. However, these traditional sources of energy contribute to alarming level of pollution in most Indian cities. The transport sector accounts for nearly 18% of the total energy consumed in India, second only to the industrial sector. In India almost half of the consumption of petroleum products is due to transport activities. This demand and dependency will grow if proper action is not taken. Out of the 142 MT CO_2 emissions released by the transport sector in 2007, 87 percent were on account of road-based vehicular activities. If no action is taken, overall transport CO_2 emissions can come close to 1000 MT by 2030, a fourfold increase from 260 MT in 2010 [4], it's a reason why state and central government both are working on finding ways to boost alternative energy sources. The electrical vehicle segment happens to be one of the thrust areas for growth as a result the government of India is planning to make India 100% electrical vehicle by 2030.

While thinking on some alternative energy sources the wind power option for EV charging. It's found that this technology is already cost competitive means that the levelized cost of wind power electricity is same or lower than from coal and it would not require government support. By 2019 the solar power has become cheaper than imported coal in India. Solar energy is a major strategic option not only for nation's energy security and electric system diversification but also an opportunity to bolster country's solar power equipment manufacturing base. As on February 2021 India has already installed 91 GW of renewable energy capacity. The mission solar of Indian

Government has a target to install 100GW of solar plant by 2022 and while achieving it the nation will become one of the three largest solar players behind China and Japan. Several companies like ABB, Magenta Power, Charge point, Levition, manufacturing, Schneider Electric, Siemens AG and tesla are working for global EV charging station market. The production of solar panels results in carbon emission but they can become carbon neutral and last for 15 to 20 years on an average.

Electric vehicle supply equipment with charging infrastructure is a necessary precondition for mass adoption of EVs. Building the necessary charging infrastructure is one of the prime agendas of the government. Policy makers will have a proper road map for implementing the EV charging scheme with financial solutions and as per standards. The electric mobility policy is currently looked by both state and central government. Presently EV policies have been drafted by 12 states (drafted and approved) while the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME II) scheme operates at the central level [5]. Its need a proper assessment that the state and central government policies are sufficient to build a conducive EV charging network in India.

In India under the FAME II policy Indian Government has allotted INR 1000 crore for charging infrastructure. The point of consideration of the first phase of charging stations will be megacities, National highways and corridors. Then the focus will be on million-plus cities, state capitals, Union territories and smart cities. The scheme definitely motivates the interlinking of renewable energy and the use of smart grids but somehow the missing element will be outline specification of the same. The specified targets are as under.

- At every 3×3 km grid there should at least one charging station.
- At least one charging station at every 25 km on both sides of highways and roads
- At every 100 km on highways and roads one fast charger.

Department of heavy industries sanctioned 2636 new charging stations across 62 cities and Union territories under the scheme [6]. The highest charging station a 317 number was allotted to Maharashtra and Karnataka and Tamilnadu were allotted 266 and 256 stations respectively. The work for 2600 charging stations will be allotted to Energy Efficiency services limited, Rajasthan Electronics and Instruments Limited, Power Grid corporation of India, National thermal power commission etc. [7]. In September 2020 a 241 number of charging stations were also sanctioned by the Ministry of Heavy Industries and Public Enterprises[8].The department of heavy industries has also invited proposals for a construction of 2,877 number of EV chargers on highways and expressways in October 2020[8].Recently the ministry of power has made an announcement to set-up charging infrastructure across 69,000 petrol pumps in India[9].The guideline for EV charging in India were published by the Ministry of power in October 2018.It gave delicensing for setting up of public charging station in India and permitted private charging. Those who are setting up public charging stations would also be provided with connectivity on priority basis. It was also decided that the bureau of energy efficiency will be the central nodal agency to coordinate the rollout of public charging infrastructure. The 12 states in India have issued dedicated EV policies. The Andhra Pradesh and Uttar Pradesh EV policies have targets of 0.1 and 0.2 million charging stations, to be built by 2024[10].Bihar aims to have chargers located at every 50 kilometer on all highways[11].Many states in India provides a 25 percent capital subsidy subject to various conditions such as subsidy ceilings on how many stations will avail of the sheme.For example Madhya Pradesh provides a 25 percent capital subsidy on all small charging stations to an amount of 0.15 million for the first 300 chargers[12].In states like Andhra Pradesh, Delhi and Karnataka reimbursement of the net states good and service tax(SGST) are provided. Karnataka state government is providing Interest free loans for setting up of charging stations [13]. Tamilnadu government is providing incentives in terms of 100 percent exemption from Electrical tax [14]. The eleven Indian states like Gujarat, Assam, are providing a special EV tariffs for EV charging stations [15]. Indian states Delhi, Maharashtra, Bihar and Telangana have issued directives aimed at setting up charging stations in residential and nonresidential spaces. Non-financial incentives also play an important role in incentivizing the charging ecosystem. States like Gujarat, Bihar, Delhi, Maharashtra, Punjab, and Telangana have issued directives aimed at setting up charging stations in residential and non-residential spaces. To establish and set reserved parking spaces and common charging points in petrol pumps and residential and non-residential buildings is encouraged. States like Madhya Pradesh and Telangana encourage the use of renewable energy for EV charging as well.

The level of charging is shown in the table 1 below [7]

Table 1: Level of charging

Charging levels	Details with specifications	Uses
Level 1	120 volt AC single phase, 16ampere, 1.9 kW, onboard, 12-20 hours charging time.	Residential and small commercial charging stations. Most EVs have a portable 110 volt onboard charger that will work with any standard home outlet.
Level-2	AC single phase 240 volt, 80 ampere, 19.2 kW onboard charger, 4-6 hours charging time.	Residential charging points and some business and commercial points are of level-2 charging type.
Level-3	1000VDC/450VAC, 400amp/200amp, 3phase/DC, 400kW off board charger, charging time less than 30 minute.	For long trip travellers.

Design of charger and implementation of charging technique is very important element of any charging station. Several battery chargers were found in the literature and can be classified according to different criteria. The first classification deals with the battery charger location, which can be inside or outside of the vehicle. Those battery chargers that are placed inside of the vehicle are called on-board battery chargers, whereas the off-board battery chargers are placed outside [16],[17],[18]. Onboard or off board chargers can have unidirectional or bidirectional power flow capability. Hardware requirements are reduced by unidirectional chargers and they also simplify interconnection issues with reduced battery degradation [19],[20]. A bi-directional charging system supports charge from the grid, battery energy injection back to the grid and power stabilization with adequate energy conversion [21]-[24]. Typical on-board chargers limit high power because of weight, space, and cost constraints [25], [26]. They can be integrated with the electric drive to avoid these problems [27]–[29]. Onboard charging systems can be conductive or inductive [30]. The charging systems those have a direct physical contact between the connector and the charge inlet are conductive chargers [16] whereas inductive chargers will transfer the power magnetically. Although, some works deal with moving chargers [30], inductive chargers are mainly considered for stationary slow charging applications [31][32]. Types of conductive charging levels with appropriate power rating are listed in table 4.1. Level-1 charging is defined for onboard charging for 1-phase 120 volts AC, 16 ampere and of 2kW rating. Level 2 charging systems are also onboard charging systems with 1-phase 240 volts AC system, 80 ampere maximum current and 19.2 kW maximum power rating [33],[34]. Level-3 charging systems are off board charging systems with 3-phase 400 volts AC up to 63 amperes maximum current and 43.7 kW of power rating.

Basically, 3-phase AC supply is converted into DC and directly applied to the EV battery pack. Level 3 DC Charging (defined for off board charging system): 300–1000 VDC, max. 400 amps current and 400 kW of power can be supplied directly to charge electrical vehicles [35], [36]. Mode 1 is the most basic charging mode. The maximum RMS current is 16 A and no specific connector for EV is required. Both 1 and 2 modes are considered slow charging modes. They are expected to take place in residential areas through common household outlets overnight and allow reaching battery full capacity before morning and for commercial charging plots also [37]-[38]. The level 3 chargers require high power whereas the Onboard battery chargers are power limited because of their weight and volume constrains, so that they can be used for battery charging for level 1 and 2. In some cases, on-board battery chargers are integrated with the electric drive of the vehicle, in order to avoid additional extra inductors and switches which would only be employed for charging the battery [39-41]. In contrast, off-board battery chargers are mainly designed for battery charging modes level 3, since they are not subjected to weight and size limitations. Table 1 shows different levels of battery charging.

Recharging EVs are accomplished by connecting to an electric vehicle charging equipment, also referred as Electric Vehicle Supply Equipment (EVSE). It’s the conduit, control, and monitoring device which connect the vehicle to the electric grid

[42].

The location of level 1 or level 2 charging station is typically below the array. Level 1 charging station can be used where parking times are long such as at offices as these are the slowest but least expensive charging scheme. Where the parking time shorter, level 2 charging stations are preferred. Level 3 are rapid chargers for long distances. These charging stations can be placed at highways, shopping centers, restaurants for people to charge their vehicle and reduce range anxiety.

In this work adaptively tuned Genetic algorithm based Proportional Integral Derivative control based EV charging station for fast charging of EV batteries is implemented. The Genetic algorithm based controller tuning overcomes the disadvantage of the conventional PID tuning of peak overshoot, undershoot and ripples in current and voltage waveforms. The steps for sizing of the charging station with standalone PV system components is explained and this design steps are equally useful for any topology related to vehicle fast charging or slow charging application. Below mention table shows the variety of battery that is used for vehicle fast charging application for different manufacturer's and all can be charged by proposed charging station design.

Specification of Li-Ion batteries for some well-known manufacturers is shown in table 2

Table 2 : Electric car battery specification of different manufacturer

Sr No	Electric car manufacturer	Battery specification
1	Bosch mild hybrid car	48 V,0.576 kWh,12AH
2	Mitsubuhsi i-MiEV	16kWh, 330V, 30 minute DC fast charging at 150 amp (up to 80%),48AH
3	Nissan Leaf	24kWh, 360V, 30 minute DC fast charging, 125 amp (up to 80%),66AH, Max power 90 kW.

Fast charging station is specifically designed for charging electrical batteries. As shown in table 2 the ratings of EV car battery varies at 48 volt, 12 AH to 360 volts, 66AH. The maximum power of Nissan leaf battery is 90kW. The individual mode for charging batteries has been taken as 90kW. For designing a fast charging station, it is very much essential to calculate the specifications of different key components of fast charging station. The complete design procedure is explained in following subsections.

Parameters to be considered for evaluating charging station capacities are shown in Table 3

Table 3: Parameter selection for evaluating rated converter capacity fast charging station

S.No	Parameter	Explanation	Value
1	K_{load}	Overload factor for charging station	10%
2	N	Maximum number of vehicles to be kept at charging station.	05
3	$\cos\varnothing$	Power factor to be maintained	0.92
4	P_{max}	Maximum capacity of individual node.	90kW

Reduction in the time required to charge EVs is one of the primary factors that positively influence the adoption of electric vehicles. Equation (1) demonstrates charging station capacity rating S_{rated} in kVA.

$$S_{rated} = \frac{K_{load} \times N \times P_{max}}{\cos\varnothing} \quad (1)$$

Equation one demonstrates charging station AC-DC converter capacity in kVA. Using parameters of table 3 the kVA capacity of converter is 538 kVA.Specification of actual Generator rating is shown in table 4.

Table 4: Specifications of Generator fast charging station

S. No	Name of parameter	Rating
1	No of phases and frequency	3-phase 50 Hz
2	kW	5000
3	PF	0.92
5	Stator (Grid) supply voltage)	20 KV
6	Stator current	16.794 KA
6	Rotor voltage	340 volts
7	Rotor current	4.04KA
8	RPM	3000

3-phase AC supply of 20KV has given to primary winding of three phase transformer. At secondary winding of transformer, a voltage source converter based three phase AC-DC converter has been connected through L-C-L filter. The function of transformer is to provide required voltage level for 3-phase AC to DC converter. A specification of transformer is shown in table 5.

Table 5: Specification of transformer for fast charging station

S. No	Name of parameter	Rating
1	No of phases and frequency	3-phase 50 Hz
2	kVA rating &configuration	750, Star/Delta
3	Primary winding voltage	20 KV
4	Secondary winding voltage	750 V
5	X/R ratio	10

As the secondary voltage of transformer is 750 volts. The DC bus voltage for the proposed charging scheme is given in equation 2:

$$V_{dc} \leq \frac{3 \times 1.414 \times V_l}{\Pi} = 1000V \tag{2}$$

$$kVA = \sqrt{3} \times VL_{(sec)} \times I_{L(sec)} \tag{3}$$

$I_{L(sec)}$=Ia=AC RMS current of 6 pulse converter=577.37=580 ampere

I_d=DC current of AC-DC converter= $I_{L(sec)}$×1.225=580×1.225= 710.5 ampere. Following system parameters shown in table 6 is used for fast charging system design.

Table 6: System parameters for AC-DC converters for fast charging station

S. No	Parameter	Value
1	THD (Total harmonic distortion)	5%
2	Fsw (switching frequency)	5kHz
3	RAF (Ripple attenuation factor)	0.20
4	Δr(Current ripple)	10%
5	Δx(Voltage ripple).	20%

The LCL filter for charging station is shown in figure 1 with the design steps.

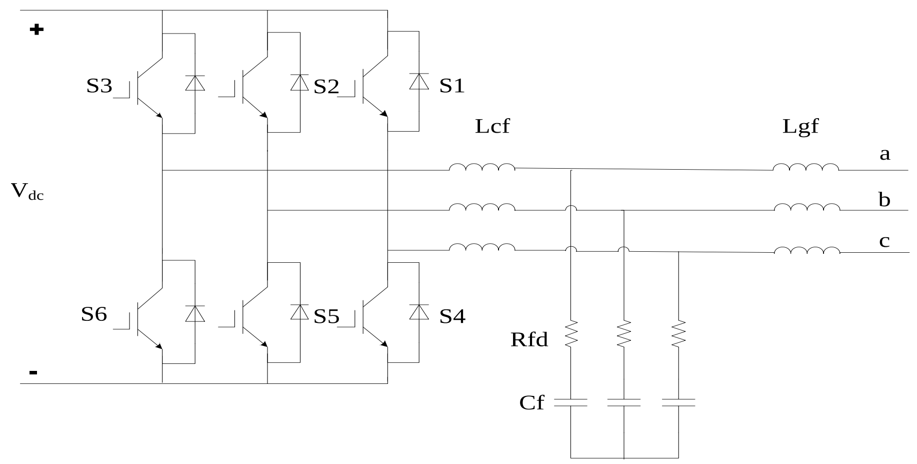

Figure 1: Three phase converter with passive LCL filter [17–18].

Figure 1 shows a converter with a passive LCL filter. Parameters such as DC voltage, switching frequency, modulation index, current, and total harmonic distortion (THD) affects the selection of the converter side inductance. In contrast, the reactive power, resonance frequency, and ripple attenuation factor (RAF) affects the selection of capacitance and grid side inductance. The converter side inductance L_{cf}, filter capacitance C_f, and grid side inductance L_{gf} are determined by using equation 4, 5, and 6 respectively. Equation 7 denotes resonance frequency and 8 the value of damping resistor.

$$L_{cf} = \frac{V_{grid}^2}{S_{rated} \times THD \times 2\pi f_{sw}} \times \sqrt{\frac{\pi^2}{18}\left(\frac{3}{2} - \left(\frac{4 \times 1.732 \times ma}{\pi}\right) + \frac{9}{8} \times ma^2\right)} \tag{4}$$

$$C_f = \frac{0.05 \times S_{rated}}{2 \times \pi \times f_{grid} \times V_{grid} \times V_{grid}}, \tag{5}$$

$$L_{gf} = \frac{RAF + 1}{RAF \times C_f \times 2\pi \times f_{sw}^2} \tag{6}$$

$$w_{res} = \sqrt{\frac{L_{inv} + L_{grid}}{L_{grid} \times L_{inv} \times C_f}}, \tag{7}$$

For L_{cf} is 0.57 mH and L_{gf} is 0.25 mH and C_f= 152µf

A damping resistor R_d is given by

$$R_d = \frac{1}{3 \times C_f \times W_{res}} \tag{8}$$

The designed parameters obtained are summarized in Table 7.

Table 7: Calculated designed parameters of AC-DC converter for fast charging station

S.No	Parameter	Value
1	S_{rated}	538 KVA
2	V_{dc}	1000 V
3	L_{cf}	0.57mH
4	L_{gf}	0.25mH
5	C_f	152 µf
6	W_{res}	2929Hz
7	R_d	1 Ω

The half bridge DC-DC converter is connected to the proposed GA-PID tuned AC-DC converter. It is shown in figure 2.

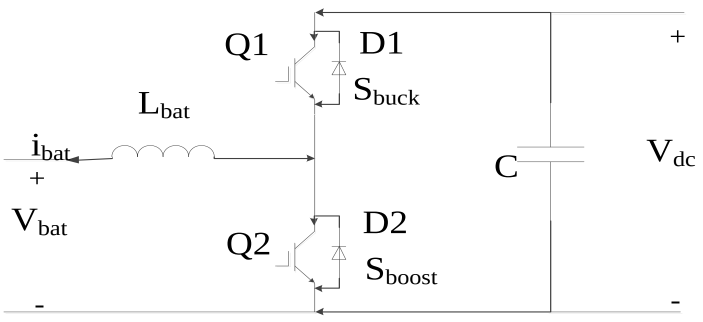

Figure 2: Half-bridge DC-DC converter

Figure 2 shows simple configuration of half bridge DC-DC converter. Inductance depends on DC bus voltage, Duty cycle, switching frequency and Ripple current. In the buck (charging) mode, the DC Bus voltage acts as the input voltage (V_{in}) and the battery voltage is the output voltage (V_{out}) of the converter. T1 switch operates in a complementary way with Diode D_2. The duty cycle of T_1 is represented by DT_1 with a fixed switching frequency, $f_{sw.}$

During the conduction period of buck switch, the voltage loop according to KVL is

$$V_{in} - V_{out} - L_{batt} \frac{di_{batt}}{dt_{on}} = 0 \tag{9}$$

$$V_{in} - V_{out} - L_{batt} \frac{dibatt}{D_{T1}} f_{sw} = 0 \tag{10}$$

Rearranging

$$(V_{in} - V_{out})D_{T1} = L_{batt} \times \Delta i_{batt} \times f_{sw} = 0 \tag{11}$$

During the conduction period of Diode D_2(When T1 is off), the KVL loop is

$$V_{out} - L_{batt} \frac{di_{batt}}{dt_{off}} = 0 \tag{12}$$

$$V_{out} - L_{batt} \frac{\Delta i_{batt}}{(1 - D_{T1})} f_{sw} = 0 \tag{13}$$

$$V_{out}(1 - D_{T1}) = L_{batt} \times \Delta i_{batt} \times f_{sw} \tag{14}$$

Equating terms $L_{batt} \times \Delta i_{batt} \times f_{sw}$ in 4.13 and 4.14

$$(V_{in} - V_{out})D_{T1} = V_{out}(1 - D_{T1}) \tag{15}$$

Therefore, the output voltage is related to the input voltage by,

$$V_{out} = V_{in} \times D_{T1} \tag{16}$$

$$D_{T1min} = \frac{48}{1000} = 0.048$$

With the duty cycle range, the inductor value required to maintain a mean charging current of 100A with a current ripple of no more than 1% (2A peak to peak) is determined using a rearrangement of 14

$$L_{batt} = \frac{(V_{out})(1 - D_{T1})}{\Delta i_{batt} \times f_{sw}} \tag{17}$$

$$L_{batt} = \frac{48(1 - 0.048)}{2 \times 5000} = 4.5mh$$

It can be reverified by the equation shown below

$$L_{batt} = \frac{V_{dc} \times D}{f \times \Delta I} \tag{18}$$

ΔI(Ripple current) =2%

L=4.8mh

So, L=5mh

f=5kHz

The DC bus capacitance calculated as per the equation shown below.

$$C_{dc} = \frac{S_{rated}}{V_{dc} \times V_{dc}} \times \frac{T \times \Delta r \times \cos\emptyset}{\Delta x}$$

=49mf

The DC bus voltage of 1000 volt is designed as per the Bharat standards. Currently, due to technology advancement in power electronics the single IGBT is also available with the rating of 1700 volt and 600 ampere and the modular IGBT are available at a rating of 6500 volt and 1700 amp and sometimes even with higher rating. So, practical implementation with communication protocol, BMS (Battery management system) with EVSE (Electrical vehicle supply equipment) is possible.

Control scheme of EV fast charging station is explained below.

The control scheme of fast charging station is divided into two parts.

1. Control scheme for 6-pulse AC-DC converter
2. Control scheme for DC-DC converter

The control scheme for both has been explained as below.

The control scheme for AC-DC converter consists of 6-pulse voltage source converter providing the DC bus voltage up to 1000 volt. The control scheme of DC-DC converter consists of constant voltage charging for charging vehicle batteries at terminals of half bridge DC-DC converter. The control scheme of DC-DC converter has been implemented first by PI control strategy and then by GA-PI controller. This was done to eliminate the drawbacks of peak overshoot and undershoot ripples and improvement in steady state error of battery voltage and current waveform.

The Control scheme for AC-DC Converter *is* explained below

Figure shows the control scheme of charging station. A dq-frame based cascade control is utilized. It has voltage loop as outer and current loop as inner loop. PLL will do Synchronization with the grid voltage. The DC bus voltage is controlled by d-axis outer loop, and the inner loop controls the active AC current. As shown in figure 3 the DC voltage V_{dc} is monitored and compared with a reference value V_{dcref} to generate an error signal in terms of reference current signal i_{dref}. Similarly, the reference RMS voltage signal is compared with actual value of voltage signal V_{rms} to generate an error signal in terms of reference current signal i_{qref}. Additionally, dq decoupling-terms ωLinv and feed-forward voltage signals are added to improve the performance during transients.

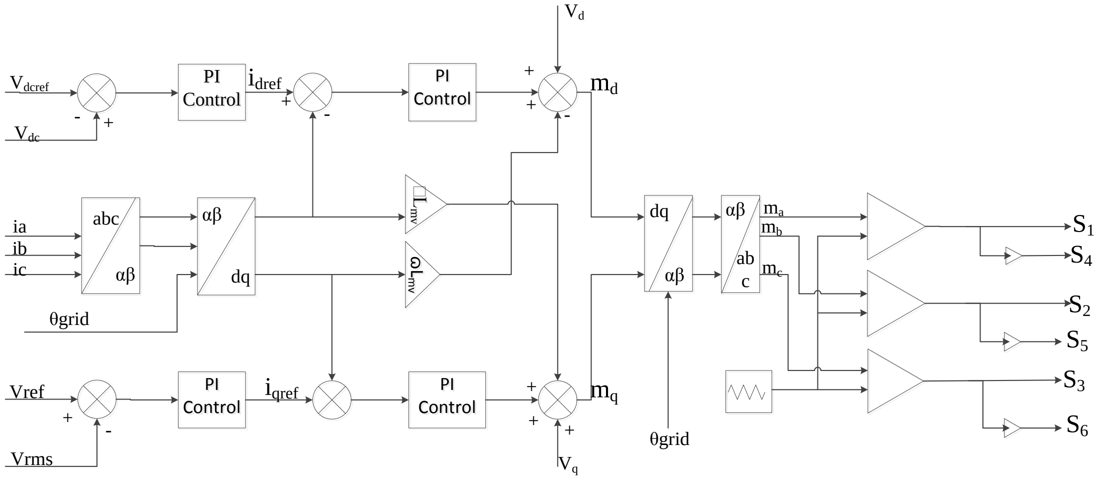

Figure 3: Control scheme of the charging station

The Control scheme for DC-DC Converter *is* explained below

Battery charging at half bridge DC-DC converter terminals is done by constant voltage charging method. While charging the batteries, the nominal battery voltage is compared with the set reference voltage. Simulation is performed initially while proportional integral action performed and operating buck switch of half bridge DC-DC converter to charge the vehicle batteries. The same set of battery charging readings has been taken by Genetic algorithm tuned controller (updated GA-PI controller) in which the KP, KI parameters are updated automatically to reduce the overshoot, undershoot, steady state error and ripples in battery voltage and current. The strategy for constant voltage charging using PI control technique is shown in Figures 4 and GA-PI tuned controller for constant voltage battery charging is shown in figure 5.

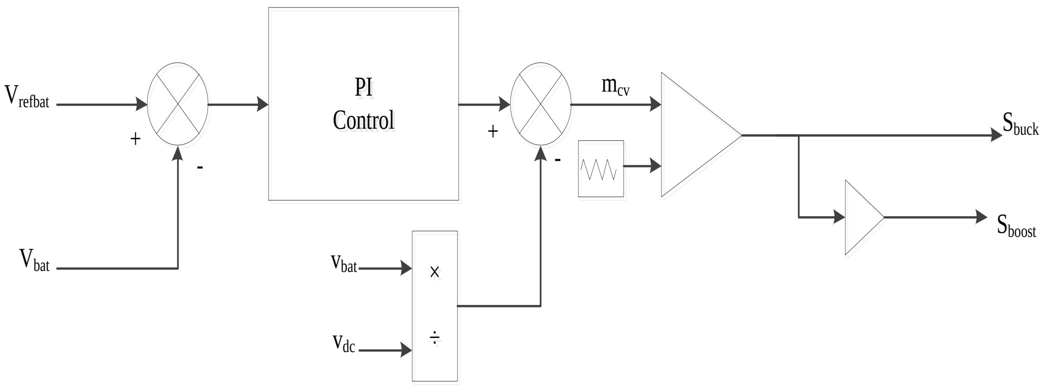

Figure 4: Constant voltage charging using PI control technique

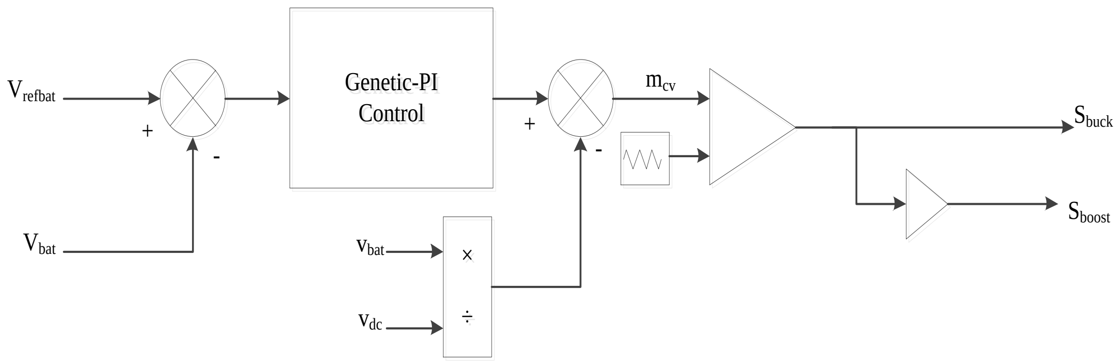

Figure 5: Constant voltage charging using Genetic control technique

The Genetic algorithm will update the parameters online for DC-DC converter, while batteries being charged on constant voltage mode so that overshoot/undershoot in the battery voltage and current waveform is reduced and also to minimize steady state error. The Genetic algorithm developed for battery charging application is explained in flow chart as shown below.

The main objective of using Genetic Algorithm is to maximize the value of KP and KI so that the overshoot and undershoot of battery voltage and current waveform are reduced and steady state error also minimized. The steps for performing Genetic algorithm are explained below.

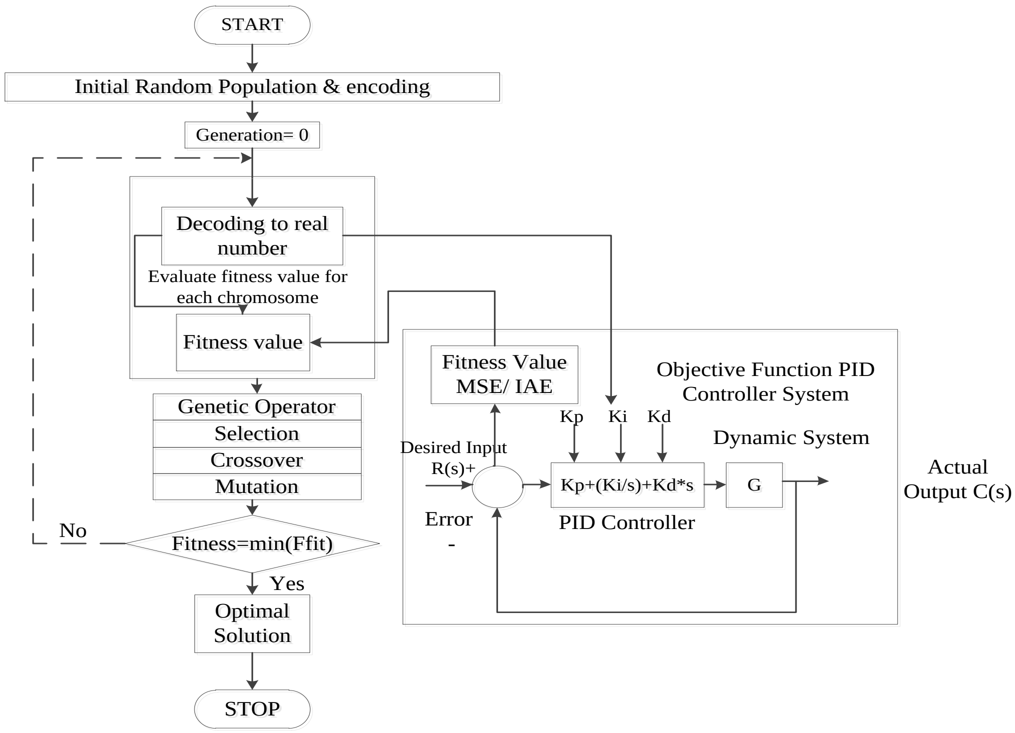

Figure 6: Flow chart implementation of GA-PI controller tuning

A GA (Genetic algorithm) is an iterative optimization procedure that can be used to solve nonlinear complex equations and optimize complex problems. A GA handles a population of potential solutions known as individual or chromosomes that evolve iteratively by using the probabilistic transition rules instead of the deterministic rules. Each iteration of the algorithm is termed as generation. The problem solution is retrieved through a fitness function and genetic operators such as reproduction, crossover, and mutation. Figure 6, displays that the first step for implementing the GA-PI controller tuning process is the random population initialization. Population (mating pool) is represented by a binary string known as a chromosome. Performance of individual is measured and assessed by the objective function that assigns a number known as fitness to every individual. The survival of the fittest strategy is applied while assessing the fitness of each chromosome. In this case, the error value is used to assess the fitness of each chromosome. If a termination criterion is not satisfied, then three operators, reproduction, crossover, and mutation, are applied to update the population of the strings until the error is minimized.

Table 8: Parameters used in GA'S

S.No.	Variable	Value	Remarks
1	Pop size	10	Generally up to 100
2	Maxgen	10	Equal to the pop size
3	Length	09	Length of the genotype
4	P_{cross}(Probability of the crossover)	0.6	This implies that 60% offspring is formed from the crossover.
5	Pm (Probability of Mutation)	0.01	If there is 1% mutation probability, then 1 out of 100 bits will be flipped.

Table 8 displays the parameters used with their values for the vehicle battery charger simulation when GA is used.

The block diagram of a control system structure with GA-PI controller is shown in Figure 7, in which the parameters of the conventional PI controller are optimized using a GA. In this algorithm online updation of PI control parameters is done using genetic algorithm such that KP and KI constants are updated and auto tuned.

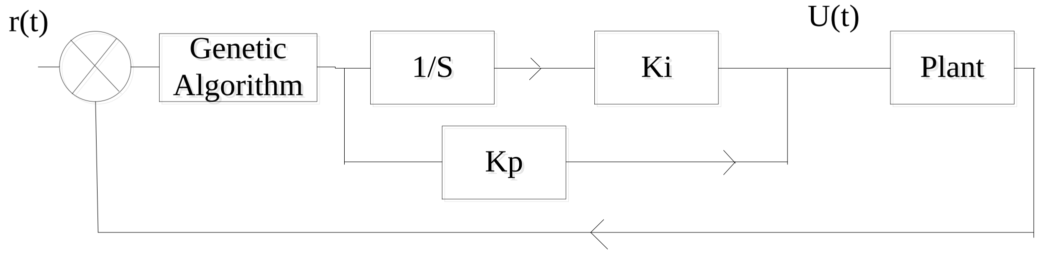

Figure 7: Block diagram of the GA-PI controller.

In this sub section simulation results were discussed in detail for two methodologies:

Constant voltage charging of batteries

1. PI control algorithm
2. GA-PI control algorithm

The parameters like battery voltage, battery current, DC bus voltage, source current harmonics etc were compared for both the controller tuning techniques mentioned above. Also, the obtained results were compared in terms of peak overshoot, undershoot, ripple and steady state error.

The vehicle battery is charged at the DC bus voltage with the constant voltage charging scheme. The results obtained while charging a 12 Ah battery at nominal 48 V to a max set reference voltage of 55 V is shown in figure 8. Overshoot and undershoot problems (3.63% of the rated value) were observed when the set voltage has reached. Figure 8 shows battery current waveform for charging an EV battery on constant voltage mode using PI control technique. Undershoot and overshoot issues had obtained in battery current waveform. Ripples were also high in waveform

Figure 9 shows the battery voltage of GA-PI based controller tuning applied for charging the battery. The battery has been charged up to 55 volt. The waveform in the figure reveals that the issue of overshoot and undershoot is absolutely eliminated and the steady state error of waveform is improved when the desired voltage has obtained. Overshoot and undershoot problems (3.63% of the rated value) were observed when the set voltage is reached. Figure 9 shows battery current waveform while charging a battery at 48 nominal volt with GA-PI controller tuning. Comparing the results of figure 8 to 9, problems associated like undershoot, overshoot and ripple in battery current waveform have been reduced by Genetic Algorithm based charging battery with auto tuning and updating parameters of PI controller.

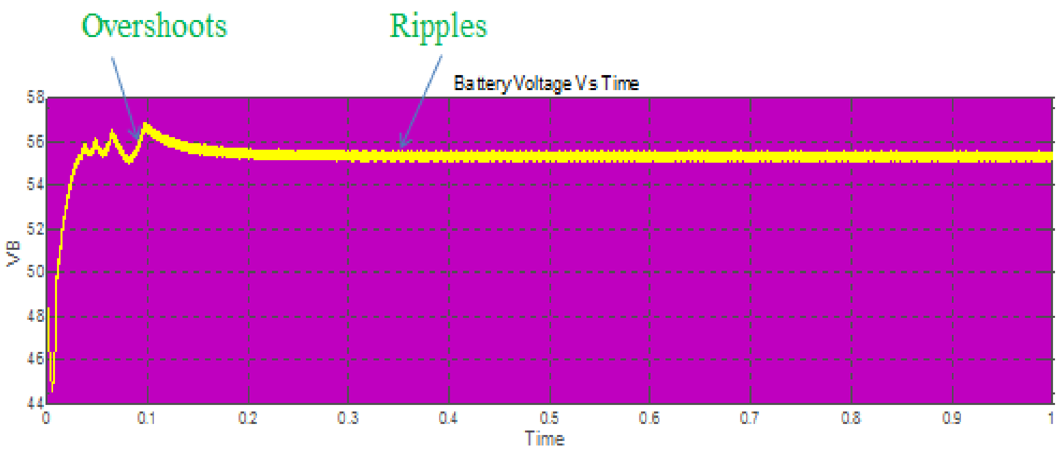

Figure 8: Voltage waveform of charging of 48 volt EV battery using PI controller

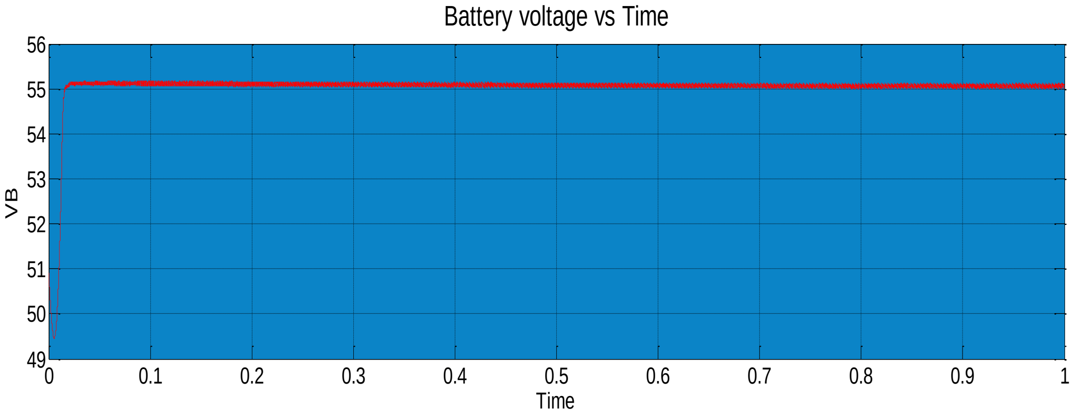

Figure 9 : Voltage waveform of charging of 48 volt EV battery using GA-PI controller.

Table 9 lists the optimized parameters obtained when the simulation is carried out with Genetic algorithm using Matlab Simulink for 48 volt battery.

Table 9: Optimized tuning parameters obtained using GA-PI controller

Sr. No.	Kp	Ki	Rating	Reference Voltage	Remarks
1	0.2694	0.1270	48 V 12 Ah	55 V	Charging

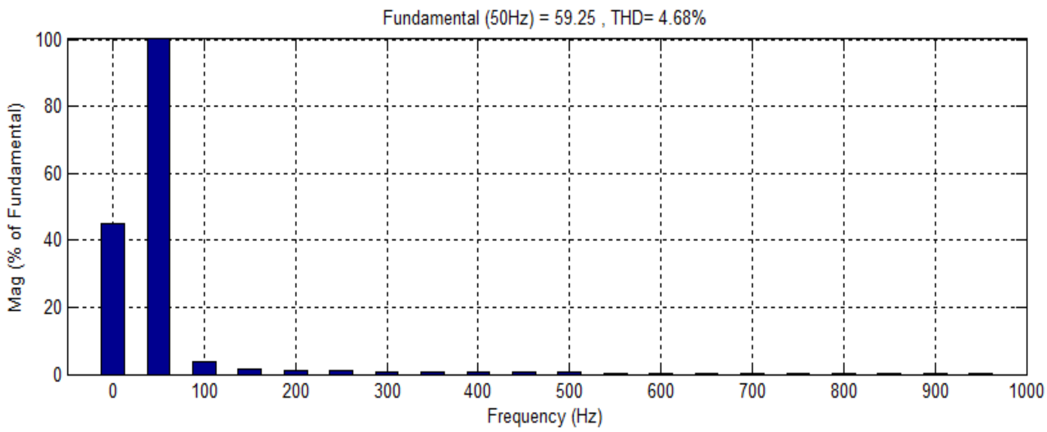

Figure 10: Current harmonics spectrum of 48 volt EV battery using PI controller

Figure 10 shows source current harmonics of 48 volt EV battery while charging with PI controller tuning. For batteries with PI tuned algorithm, the value of current harmonics is slightly higher as compared to GA-PI tuning technique. Figure 11 shows source current harmonics with GA-PI controller tuning technique. In both cases results obtained are within IEEE 5192 standards. In both the cases LCL filter works satisfactorily but with Genetic algorithm updated tuning technique the harmonics value is low.

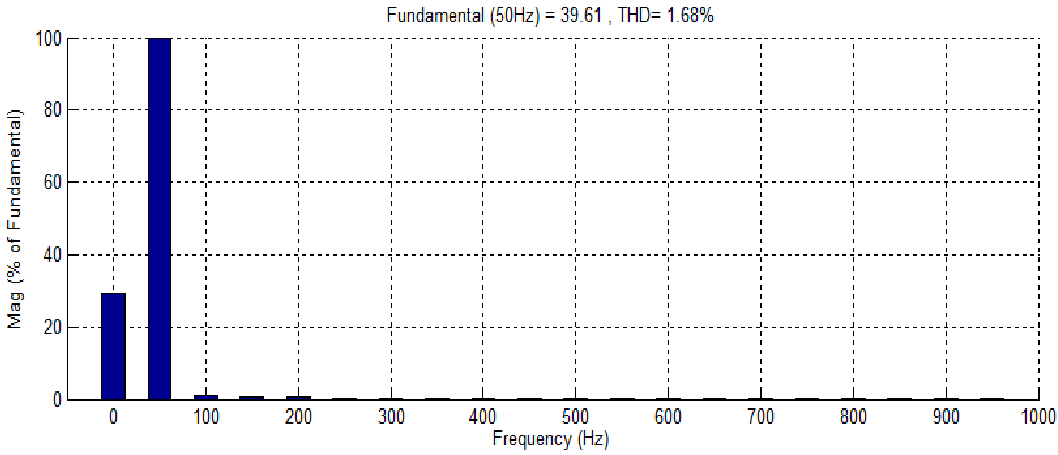

Figure 11: Current harmonics spectrum of 48 volt EV battery using GA-PI controller

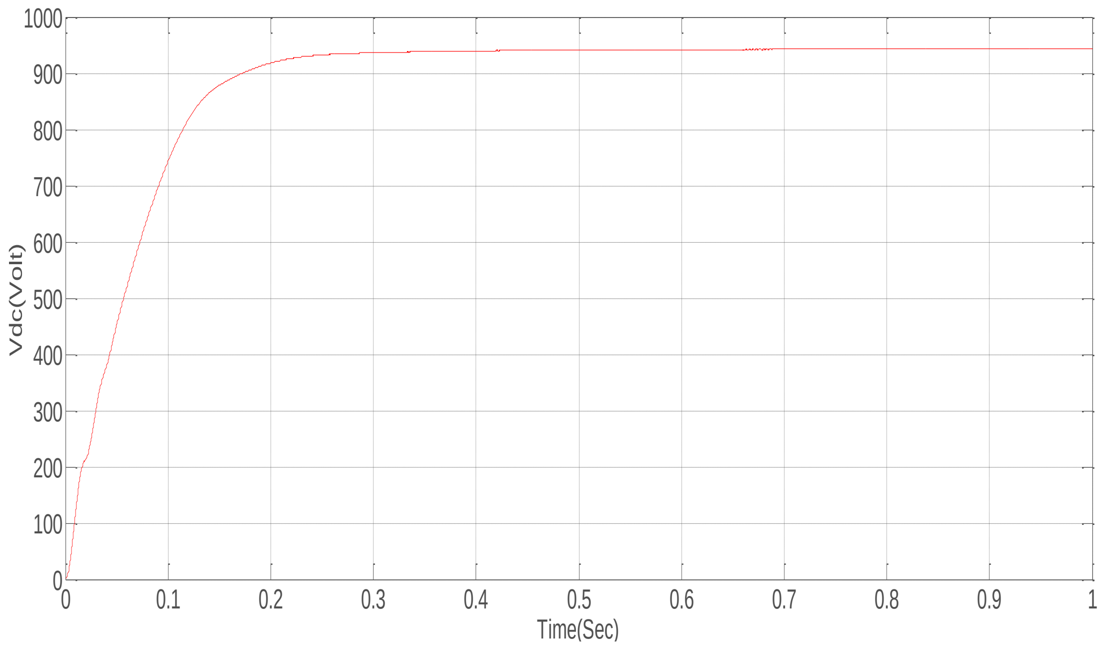

Figure 12: Variation of the DC bus voltage with respect to time.

Figure 12 displays variation of DC bus voltage with respect to time while charging 48 volt EV batteries. It is as per designed limit of DC bus voltage of 1000 volt. Similarly while charging other batteries with PI control technique and GA-PI control technique the DC bus voltage was found below 1000 volt as per the designed specification value.

The block diagram of Implementation of fast charging station with standalone solar PV system is shown in figure 13 below.

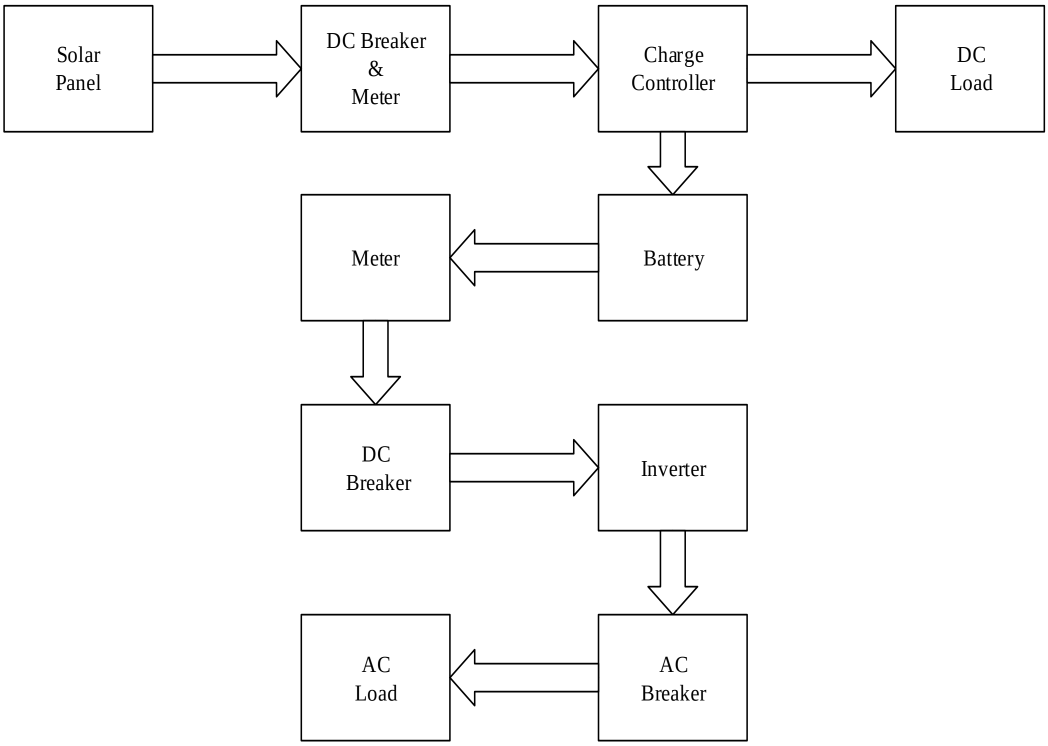

Figure 13: Standalone PV system design

The detail design steps for standalone solar PV system are explained below.

Manufactures mentioned the PV parameters under the standard test conditions i.e., temperature of 25°C and radiation of 1000 W/m^2.The design procedure for standalone solar based domestic load application, Standalone EV charging, Combination of Domestic load and EV charging is asked in subsequent steps. For optimum desired output from solar panels, we need to point them in the direction that captures maximum sunlight south if we are in northern hemisphere or north if we are in southern hemisphere. There is a simple thumb rule for calculation of tilt angle for fixed mount solar panels. Subtract 15^0 from the latitude of your location during summer and add 15^0 to your latitude during winter. The other method to find the value of optimum tilt angle for solar panels during winter is calculated by multiplication of the latitude by 0.9 and then adding 29^0.For an example if latitude of place is 34^0, then the tilt angle will be [(34*0.9) +29] =59.6^0. This method is more accurate as an angle is 10^0 steeper than in the general method. For summer the tilt angle is calculated by multiplying the latitude by 0.9 and subtracting 23.5^0. In the above case example this angle would be [(34*0.9)-23.5] =7.1^0. For optimum tilt angle during spring and fall, 2.5^0 is subtracted from latitude.

The sizing and design steps of solar PV based EV charging are explained in following subsection

Sizing of PV Array

Total W_{Peak} of PV panel capacity = Total watt hour of the load under consideration / 3.2 (P_{FG})

Note: The value of P_{FG} (Panel Generation Factor) is varying (due to climate and temperature changes) in different regions e.g, P_{FG} in USA = 3.22, EU = 293, Thailand = 3.43 etc.

P_{GF}=(Average solar Irradiance of location*Sunshine Hour)/Standard test condition Irradiance

The above formula can be modified with below mention considerations

The additional losses should be considered to find the exact panel generation factor (P_{GF}). These losses (in %) occur due to:

I. Sunlight not striking the solar panel straight on (5%)
II. Not receiving energy at the maximum power point (excluded in case of MPPT charge controller). (10%)
III. Dirt on solar panels (5%)
IV. PV panels aging and below specification (10%)
V. Temperature above 25°C (15%)

The next step is to calculate the energy demand

Total energy demand Watt-hour = ∑ (Power rating in Watt × Duration of operation in hours).

The designed of the system must be considering for the worst-case scenario i.e. The day for when the energy demand is highest. A designed system for the highest demand will ensure that the system is reliable. If the system meets the peak demand, it will meet the lowest demand. But this will increase the overall cost of the system. On the other hand, the system will be fully utilized only during the peak load demand. So, we have to choose between cost and reliability of the system.

Inverter and controller sizing

The size of the inverter should be 25% bigger than the total load due losses in the inverter.

In other words, it should be rated 125% than the total load required in watts

The charge controller voltage shall be matched with the system voltage. The standard configurations are 12, 24, and 48 volts. If you are wiring your batteries for 12 volts you need a charge controller that is rated at 12 volts.

Some controllers are voltage specific, meaning that the voltage cannot be changed or substituted. Other more sophisticated controllers include a voltage auto-detect feature, which allows it to be used with different voltage settings

To select the proper Charge Controller, you have to know the maximum output current of the solar panel and Battery Voltage. The maximum possible current that a Solar panel can generate is the "short circuit current," indicated as I_{sc}(short circuit current) in the panel's label or specs sheet. Now select a charge controller with,

Current rating more than Short Circuit Current (I_{sc}) with consideration of a safety factor (1.25 x 125 = 1.56)

Sizing of batteries

The next step is to decide the sizing of batteries

While sizing the battery some parameters are needed to be considered as follows:

Depth of Discharge (DOD) of the battery.

Voltage and ampere-hour (Ah) capacity of the battery.

The number of days of autonomy (It is the number of days required to power up the whole system (backup power) without solar panels in case of full shading or rainy days.

Also, the required capacity of batteries can be found by the following formula.

(Total watt-hours of Appliance) × (Days of autonomy) / ((Battery losses) × (Depth of Discharge) × (Rated battery voltage))

For charging one 48 volt 12 AH battery the required watt hour will be=576 watt hour. Considering 30% losses required the required watt hour will be=748.8 watt hour. The watthour is divided by the panel generation factor of site 4.5, so the total watt peak needed to charge one 48 volt battery will be 748.8/4.5=166.4-watt peak. If 110wattpeak is the available module then 166.4/110=02 modules will be required to charge 48 volt battery. The size of the inverter should be 25% bigger than the total load due losses in the inverter.so 576×1.25=720 watt inverter is at least required to charge one 48 volt battery at 1C rate. For 48 volt system ,02 days of autonomy and 60% depth of discharge the required AH capacity for solar battery will be 47AH at least. Once all the system components are known costing and finance becomes bit easier part to execute for startups.

ISSUES AND CHALLENGES TO STARTUPS

A successful start up based on solar PV based EV charging cannot be started and executed with only a passion an idea. A very high level of leadership skills with clear understanding of market, grasping opportunities of networking build up and ability to take a calculated risk are key components .Lack of awareness, multiple clearances, unorganised market, poor grid infrastructure for EV charging, lack of mentoring , lack of understanding of standards of Implementation, stringent exit policies, technological risk, unclarity of regulatory mechanisms, non availability of financial resources for initial implantation and scaling, improper business model canvas and lack of reforms keeping pace with the fast evolving market changes are some of the challenges. Smart charging will allow a certain control over a charging process. It will have different pricing and technical charging options. The time of use charging encourages customers to charge in off peak periods. With vehicle to grid(V2G) injecting power back to grid vehicles will provide ancillary services to transmission system operators

CONCLUSION

There are ample of opportunities for start up in solar PV based EV charging. But the start up creator should have a team that has a potential to understand the policies, technical understanding with cost benefit analysis. A clear business plan with identifying the investors in initial stage as well as in growth stage. The land identification for setting up the solar PV based EV charging station is also crucial. The merger with existing petrol/diesel pumps, compact setup at commercial places for PV based EV charging will be of importance. This paper shows novel GA-PID online adaptive tuning based EV charging station. It also gives understanding how to implement the EV charging station to charge number of EV batteries with standalone solar PV station. The concept will be useful both for slow charging and fast charging of EV batteries. The tuning methodology reduces the peak overshoot/undershoot and ripples in the battery voltage and current waveforms. The carbon dioxide emission will certainly reduce due to Solar PV based EV smart charging approach.

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