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Development of solar based level 3 fast charging station for electric vehicle

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***Abstract* — The attention given to the adoption of electric vehicle leads to the demand of fast charging technology adoption for electric car batteries. The suggested structure for fast charging station can be adopted to charge numerous cars at a time. it is a simplest model of fast charging station based on renewable energy. design strategy and parameters to implement in MATLAB/SIMULINK. Simulation is performed in MATLAB Simulink to observe the charging characteristic of a battery to obtain a desired response**

***Index Terms*— state of charge (SOC).**

I. INTRODUCTION

ELECTRIC vehicle now a days have improved potential of transport. it reduces the greenhouse gas emission as well as make transport comfortable and fast in comparison to ICE engine previously used [1]. Charging of electric vehicle must be environmentally friendly. it should be emission free charging electric vehicle with an AC supply cause burden on AC grid and impacts the load profile of grid to avoid such kind of situation ways are suggested to charge an EV using DC.[2] Electric vehicle use is enlarged by improving its ability to charge for such kind of improvement, there are three dc level for charging an electric vehicle

Level 1: 450V, 80 A and it can provide power up to 36kW

Level 2: 450V, 200 A and it can provide power up to 90KW

Level 3: it is the fastest level of charging it is placed at public places. this type of charging station can charge battery within 20 minutes. It can be constructed using a dc source and as well as AC using inverter. Such kind of charging station having high voltage up to 200/600V, 400A and can provide power up to 240KW.

According to power and charging level certain types of connectors are built by different manufacturers at different time there are AC Connectors as well as DC connectors. Here dc connectors are addressed

1. Combined charging system – type 1 and type 2: DC pins are supposed for AC is for communication and for the safety of vehicle
2. CHA demo: this type of connectors are used in Japan.
3. Tesla: tesla has its own connector installed in vehicle for level 1, level 2 and level 3

DC fast charging station is of more interest now a days as it is leading the world towards electrification of the transport. in future such kind of charging station play an important role in human life like gas station now a days

II. LITERATURE REVIEW

In the previous decades the road transport vehicle are using internal combustion engine(ICE) because of its high reliability, but due to rising price of fossil fuel and environmental pollution the ICE engine become so dangerous because of carbon di oxide emission due to smoke, also due to lack of fossil fuel and health hazard most of the vehicle manufacturers are searching for the alternative solution and they came up with the idea to build a vehicle which run with a natural gas like hydrogen , biomass and so on but this idea is not feasible in case of long term transportation {3}. Earlier some researchers came up with idea of electric vehicle, electric vehicle is the idea of reducing the global warming effect of gases in transportation sector because there is no tail pipe emission in electric vehicle. the exhaust of smoke by (ICE) engine doesn't just stink but also kill the human and also cause dangerous impact on all other living thing {4}. electric vehicles exist since 1900 but after some year of its manufacture its selling ratio reduces to zero because of its slow speed and expensive parts, however the use of EV for transportation died out due to improvement in ICE engine [4]. the goal in EV development is to improve its efficiency its ability to work, its safe operation with the advancement of power electronics and microelectronics that provide EV capability as comparative to ICE technology in terms of EV must provide range as similar to ICE engine and can travel fast as possible [5]. To enhance the efficiency, use and sustainability of electric vehicle the main problem is to charge the battery of electric vehicle. it was suggested that the battery of electric vehicle must be rechargeable it is of lithium, nickel, cobalt. the selection of location for the placement of charging station is a big issue. the location of charging station to select is critical it should be that much available that any location during travelling EV battery can be recharged. this problem is however solved by EV charging station placement problem [6]. The work has been done on EV to make it cost effective and less greenhouse gas emission by reducing the dependence on fossil fuel many types of charging station are suggested and the comparative analysis is made between Europe and American standard [7]. As there are different level of charging stations for electric vehicle the efficiency got impacted. The efficiency is defined as the power drawn from electric grid to charge and electric vehicle's battery. efficiency is compared

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between two level of charging station: level 1 and level 2[8]. Three level of charging stations are suggested according to power and amount of current. level 1: for power 3 to 7KW maximum current in this level is 1 10 to 16 A and the location for such kind of charging station is domestic or this level is called home charging this level of charging use single phase AC connection. Level 2: for power 3,7 KW to 22KW level 2 charging stations were suggested. Maximum current in this level is 16 to 32 A. this can be used at semi-public location with either a single phase or three phase AC connection. Level 3: for power more than 22KW having maximum current of more than 32 A this can be built either a three phase AC connection or a DC connection. the location for such kind of charging station is public. There are four different modes of EV Charging according to power different modes are classified and each mode using different connector [9] there are two types of electric vehicle chargers (on board and off board). on board charger is in electric vehicle it is different from different companies manufacturing EV while an offboard type is fixed at different location in the city like in the parking areas [10] fast charging station is proposed using AC three phase supply, but this caused burden on the grid to reduce the burden the grid is suggested to supply the average of EV charging station not the peak demand. This way grid size can be substantially reduced [11]. fast charging station is proposed using AC as well as DC source where a super capacitor is used as power bank. electric vehicle fast charging is necessary because of long distance travel [12]. DC fast charging station is suggested using invertor for operation in both V2G and G2V mode which can transfer power in both direction vehicle to grid as well as grid to vehicle [13]

III. METHODOLOGY

A. *Solar panel*

Solar panels system and EV charging station this combination brings some benefits and provide a cheap and cost-effective way to produce energy. The quantity of electricity needed to charge your EV car depends on the size and capacity of its battery. An electric vehicle battery is measured in kilowatt hours(kwh) can range between 20s to 250+kwh so when we are installing the panels, we must consider these numbers and how much energy we need to charge the EV battery the selection of panels depend upon the KW required by the battery and the efficiency of the battery solar pv array is installed on the roof of the charging station. so, there is no transmission losses

TABLE 1*: parameters of solar panel*

parameters	Value
No of series connected panels	5
No of parallel connected panels	65
Power of individual panel	305W
Open circuit voltage/Panel	64.2V
Short circuit current/panel	5.96
Input radiation	3120W/m^2
Temperature	25

B. *MPPT technique*

An MPPT charge controller or maximum power point tracker basically optimizes the match between solar panels and utility grid. MPPT operates using an algorithm which is basically a series of steps to get our desired output or results. Various algorithm can be used in MPPT, but we are using PERTURB and OBSERVE (P&O). The PERTURB and OBSERVE algorithm is also known as hill climbing method. this method works by comparing previous power stored in memory to the new power obtained from the panel. below given is the flow chart of perturb and observer technique

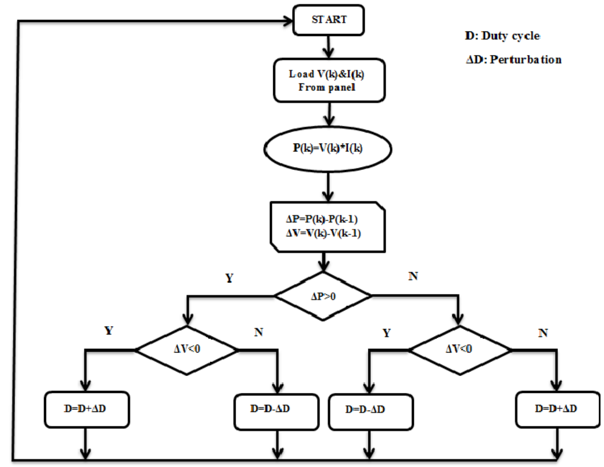

Figure 1: display algorithm for perturb and observer

C. *Boost converter*

Boost is a type of dc-to-dc converter that steps up the output voltage and steps down the current. It is one type of switch mode power supplies it must contain two energy storing elements (inductor and capacitor) as well as two semiconductor devices (diode and transistor). Boost converter also known as step up choppers

Table 2: *shows the parameters of boost converter*

Input voltage	320V
Output voltage	600V
Switching frequency	5KHz
Duty cycle	0.464
resistor	3.316
Inductor	0.0945*e^{-2}
capacitor	5.704*e^{-4}

D. *AC grid and rectifier*

Ac source is considered as a backup source to provide power to charging station when solar in unavailable. The single-phase ac source is not enough to charge a battery at level 3 so transformer is here to step up the voltages. the rectifier is a combination of no: of diodes to convert AC into DC. bridge rectifier is preferred, and capacitor is used as a filter this remove ripples from pulsating DC

TABLE 3*: shows parameter of ac to dc rectifier*

Input voltage	220Vrms
Output voltage	600V
TF pri Vrms	220
TF sec Vrms	445

Capacitor	7*e^{-6}F

E. DC bus capacitor

DC-link capacitors are used in order to provide a more stable DC voltage, limiting its fluctuations even under heavy current absorption by the converter

F. Buck converter

Buck converter is step down voltage converter. The buck converter is used in those circuits where dc output voltage needs to be lower than the dc input value. its operation is entirely inverse of boost converter. it is also switching type of power supply having two energy storing elements and two semi-conductor devices. the buck converter is placed inside the charger of each EV

TABLE 4. *shows parameter of buck converter*

Input voltage	600V
Output voltage	300V
Switching frequency	5KHz
Duty cycle	0.5
resistor	1.5
Inductor	7.5*e^{-5}
capacitor	7.69*e^{-4}

G. Lithium battery charger

Battery chargers are widely used in our daily life routine whether want to charge our phone, appliances, or our electric vehicle. A battery charger circuit may be simple sometimes, but batteries don't like crude charging voltages therefore it always recommended to use a smooth and constant output voltage charger.

H. Constant current and constant voltage algorithm

Constant current and constant voltage method basically the combination of two methods. The charger limits the amount of current to a pre-set value until the battery reaches at its pre-set voltage value. current is then reduced when the battery is fully charged this system allow the fast charging without the risk of over charging

1) Constant current method:

It continuously observes the state of charge of battery, when it reaches till 95% of its rated voltage than constant voltage charging is started. it is done by using PID controller by setting a reference voltage instantaneous value of current is compared at every instant with a reference voltage and the difference is given to PID controller

2) Constant voltage method

In CV mode the value of battery voltage is compared with a reference value and the difference in both is used to calculate the reference current by which comparison is made to the actual current. difference between both currents is fed to PID Controller

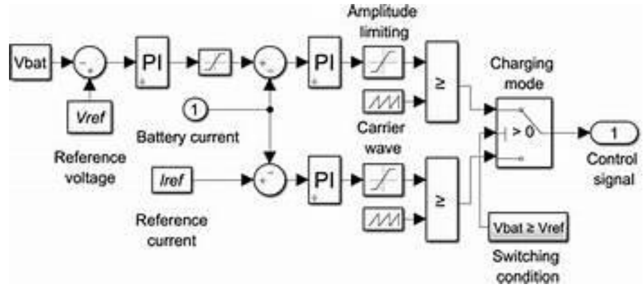

Fig 2: block diagram of CCCV mode of charging

I. Lithium battery

The batteries used in tesla cars if of course similar to other manufactures of EV. major issue while using lithium battery is its cost, efficiency, and life cycle. tesla uses cylindrical shaped batteries such that it improves its efficiency cost and flexibility

IV. CALCULATIONS

A. Design of PV array

Number of panels requires is obtained by considering sun hours, day of autonomy, system load and efficiency of battery as well. equation (1) represents the formula for calculating energy from panel. Equation (2) represents for calculation power

Sun hours for Jamshoro	= 7	
Efficiency of battery	= 80%	
Wh of battery	= 100kwh	
Voltage	= 300V	
Battery capacity	= 333.33Ah	
Energy required by battery	= 100KWh	
Energy from panel	= (100Kwh/efficiency of battery)	(1)
	= 100Kwh/0.8	
Energy from panel	=125000wh	
Power from panel	= energy /sun hours	(2)
	=125000/7	
Power from panel	=17857.14w	
Panel connected	= 65 each of 305W	

Wh used in equation 1 is the watt-hour

B. Design of boost converter

Boost converter is design by considering duty cycle, input voltage, output voltage. the main considering variable in switching frequency which is kept constant in entire system for proper operation. equation (3) represent formula to calculate duty cycle for boost converter it is different from buck converter. equation 4 is the equation for calculating resistor. equation 5 is for inductor. equation 6 is used to calculate capacitance required

Input voltage: 320V
Output voltage: 600V

F_S	= 5KHz	
Duty cycle	$= 1- V_{in}/V_{out}$	(3)
Duty cycle	= 1 -320/600	
Duty cycle	= 0.464	
Selection of resistor	$= (V_{out})^2$/ power output	(4)
	$= (600)^2$/100Kw	
Resistor	= 3.316 ohms	
Inductor	$= D(1-D) * R/ 2 *F_S$	(5)

	= 0.464(1-0.464) *3.316/2*5000	
Inductor	= 0.0945 * e^{-02} H	
Capacitor	= D/R*V_0* F_S	(6)
	= 0.464 / 3.316*0.05*5000	
Capacitor	= 5.704*e^{-04} F	

In equation 1 V_{in} the input voltage, V_{out} is the output voltage D in equation 5 is the duty cycle

C. *Design of buck converter*

Buck converter is design by considering duty cycle, input and output voltage requires. to get the desired output voltage the main parameter is the duty cycle which can be varied by varying switching frequency equation 7 is the duty cycle for buck converter equation 8 is for the required resistance equation 9 is the required inductor to get the desired output. Equation 10 is the required capacitor.

Input voltage: 600V
Output voltage: 300V

F_S	= 5KHz	
Duty cycle	= V_{out}/V_{in}	
Duty cycle	= 300/600	
Duty cycle	= 0.5	(7)
Selection of resistor	= $(V_{out})^2$/ power output	
	= $(300)^2$/100Kw	
Resistor	= 1.5ohms	(8)
Inductor	= (1-D) * R/ 2 *F_S	
	= 0.5(1-0.5) *1.5/2*5000	
Inductor	= 7.5* e^{-05} H	(9)
Capacitor	= 1-D/8*L* * F_S^2	
	= 1-0.5 / 8*7.5* e^{-05} *5000^2	
Capacitor	= 7.69*e^{-04} F	(10)

V. PROPOSED MODEL

Renewable energy is preferred in place of AC grid because in AC grid electricity is however generated using fossil fuels. due to lack of fossil fuel in present era and its impact on the climate of the earth, renewable energy is promoted as it is emission less having no carbon di oxide emission, having no harmful impact on human life.

To charge a battery within less time such kind of charging station is suggested using renewable energy The below given model is for the battery charging of an electric vehicle by level 3 station and with the method of constant current constant voltage resource Figure 3 below is the block diagram of proposed model

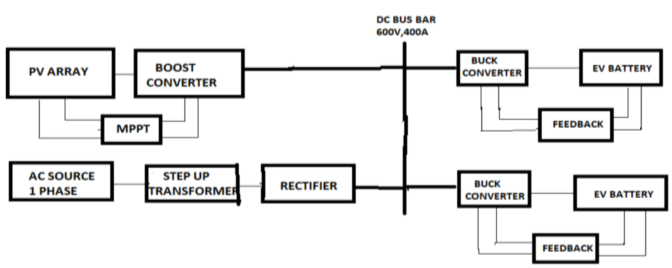

Fig 3: block diagram of proposed model

VI. SIMULATION MODEL

By considering above design parameters simulation is performed for such kind of charging station using MATLAB Simulink. parameters are adjusted according to above given tables and calculations.

Table 1 shows the parameters for solar We have used SUN POWER WTD panel of solar panel to simulate a photovoltaic system which generate voltage up to 300V

Table 2 shows the input and output parameters of boost converter by varying the duty cycle the output voltage of boost converter can be varied

Ac source is implemented using single phase AC supply having 0 phase degree supply voltage is taken as 220Vrms. To step up AC voltage single phase two winding transformer is used

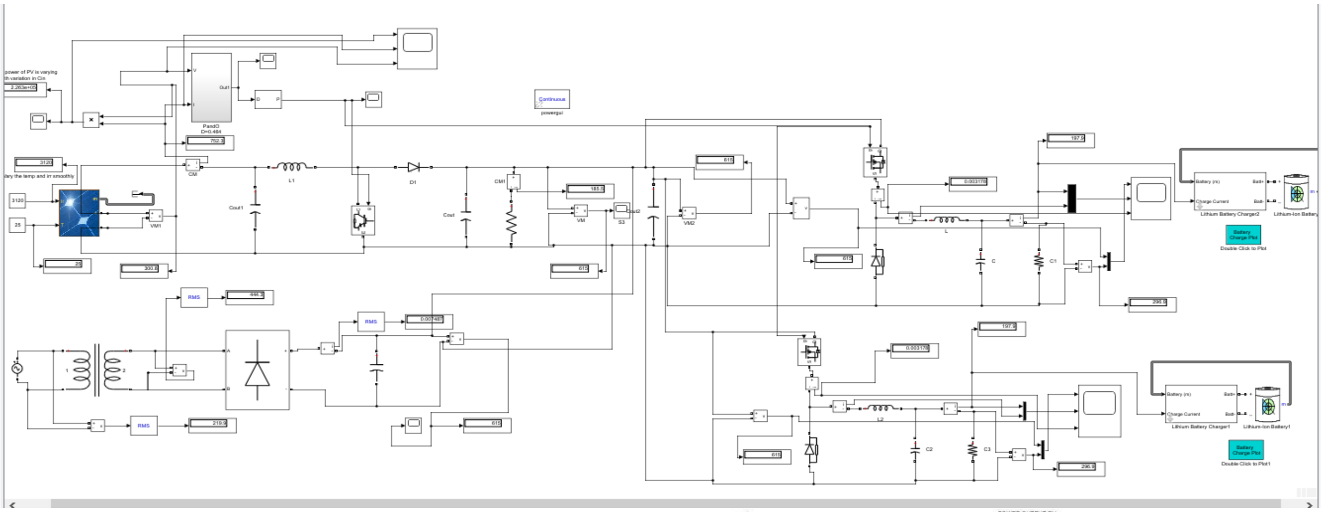

Fig 4: Simulink model of dc fast charging station

To convert AC into DC "universal bridge" is used as a rectifier from SimPower system library in which there are four diodes. it has to be selected 2 arms

The battery charger can be implemented with parameters table 4. The main purpose of battery charger is to step down the voltage and maintain CCCV mode of charging.

The battery can be made by its equivalent circuit or by direct using battery from SimPower system library

VII. SIMULATION RESULTS

A. PANEL CHARACTERSTICS

Figure 5 is the graph of solar panels on specific radiation to determine the maximum power point. it can be observed that the VI and PV characteristic of panel is nonlinear

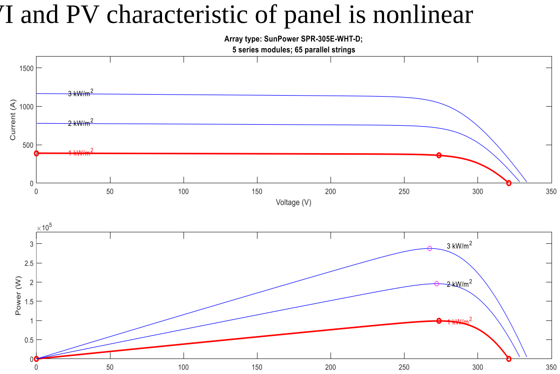

Fig 5

B. PV GENERATED CHARACTERSTICS

Figure 6 is the graph of the generated voltage power. and current of PV array

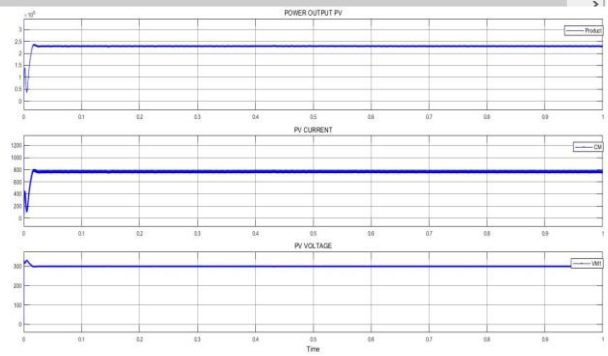

Fig 6

C. OUTPUT OF BOOST CONVERTER

Figure 7 Below is the given graphs of the input and output characteristics of boost converter

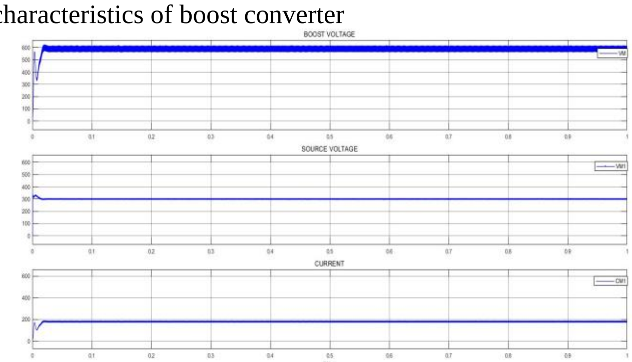

Fig 7

D. RECTIFIED VOLTAGE

Figure 8 below shows the graphical results of the backup ac source and its rectified dc voltage

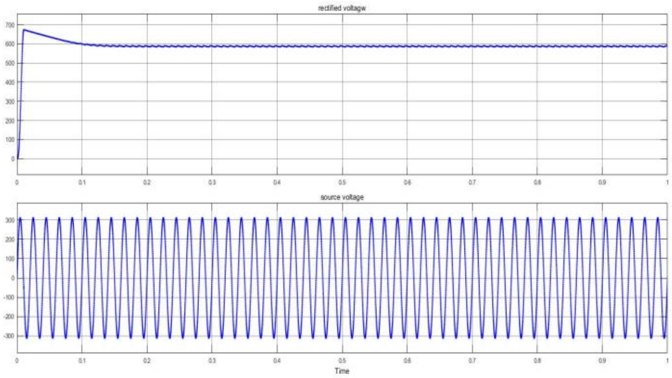

Fig 8

E. CHARGER CHARACTERSTIC

Figure 9 below shows the charger characteristic its step down voltage

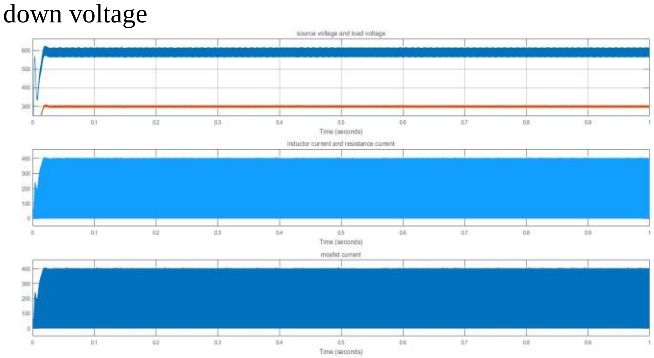

Fig 9

F. BATTERY CHARACTERSTIC

Figure 10 below is the graph of the battery voltage , battery charging current and its SOC

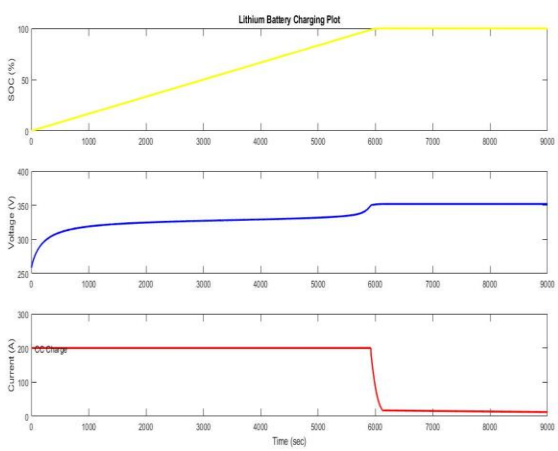

Fig 10

VIII. CONCLUSION

The above all results show the parameters and conditions required for the fast-charging station implementation in simulation, further factor get into consideration during designing hardware model

Many types of converters are used in this model and control technique for charging of battery efficiently SOC of battery, as the battery voltage reaches up to 95% of rated voltage than constant charging is stopped, constant voltage method starts. as this method can charge a battery fastly and efficiently

IX. FUTURE WORK

In future DC fast charging station, be common as gasoline pumps all over the world so that EV users can charge their batteries everywhere during travel. in future hybrid charging stations can be made using more than one renewable resource to reduce the dependency on AC grid

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