Modelling And Simulation of Charging Characteristics of Solar Powered Eletric Vehicle

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Abstract- *This work is aimed at modeling & Simulation of a distinct smart charging station for Electric Vehicles (EVs) that is suitable for DC quick EV charging while ensuring minimum stress on the power grid. Operation of the charging station is managed in such a way that it is either supplied by Photo Voltaic (PV) power or the power grid, it is also implemented for improving the stability of the grid during peak load hours.*

The PV interfaced DC/DC converter and grid interfaced DC/AC bidirectional converter share a DC bus. A smooth transition of one operating mode to another demonstrates the effectiveness of the employed control strategy. Modeling and control of the Charging are explained using PI Controller and are implemented in MATLAB Simulink. Simulations illustrate the feasible behavior of the charging station under all operating modes in terms of the Two-way interaction among PV & Electric Vehicle.

It has been recognized that EVs bring new opportunities in terms of providing regulation services and consumption flexibility by varying the recharging power at a certain time instant. This dissertation work mainly focuses on electric vehicle charging based on solar and grid charging. Here I used one new tool for automation purpose which is called MATLAB embedded function from solar to grid and back. The dissertation also discusses the potential financial incentives required to inspire EV owners for active participation in the demand response mechanism.

I. INTRODUCTION

The worldwide adoption of Electric Vehicles (EVs) is significantly on the rise over the classic fossil fuel vehicles. However, the purchase price of an EV may still the main constraint in the market since the batteries are found to be significantly more expensive. Advantageous reasons make the customers prefer EVs such as low ecological impact with no greenhouse emissions and performance improvement, etc. The energy sustainability requires consumers with environmental awareness and vision to electricity based on renewable, recent research confirms that one percent increase in renewable energies would lead to nearly 2–6% increase in EV demands.

In this chapter, the challenges of the Electric Vehicle (EV) charging stations are discussed while highlighting the growing use of distributed generators in the modern electrical grid system. The benefits of the adoption of Photo Voltaic(PV)sources along with battery storage devices are presented. Finally, the chapter ends with an introduction to the high level architecture of the proposed system along with a briefing of the content for the following chapters.

Conventional EV Charging Stations

The prospective shortage of fossil fuels and the current environmental challenges of reducing the greenhouse gases motivate the extensive research on EV systems [1]. However, the research on EVs is highly impacted by the consumer willingness for switching from using conventional internal combustion engine vehicles to EVs as an alternate means of transport. This willingness is the main factor in predicting the future demand for EVs. In [2], the authors concluded that the charging time is one of the main challenges that the EV industry is facing. Thus, this dissertation focuses on providing novel solutions for reducing the EV charging time by providing fast charging rates.

Three levels of EV charging (shown in Fig. 1.1) are undergoing research and development in the US. The EV charging levels are classified according to their power charging rates [3].

Overnight charging takes place in level I, as the EVs are plugged to a convenient power outlet (120 V) for slow charging (1.5-2.5 kW) over long hours. The main concern of level-I is the long charging time, which renders this charging level unsuitable for long driving cycles, when more than one charging operation is needed. Moreover, from the electrical grid operation point of view, the long charging hours at night overloads the distribution transformers as they are not allowed to rest in a grid system with high number of connected EVs [4].

Level-II charging requires 240 V outlet; thus, it is typically used as the primary charging means for private and public facilities. This charging level is capable of supplying power in the range of 4 - 6.6 kW over a period of 3 - 6 hours to replenish depleted EV batteries. The time required is still the main drawback in this charging level. Additionally, voltage sags and high power losses in an electrical grid system with a high penetration of level II charging are some of the challenges that are facing its widespread. Control and coordination in level II would reduce the negative impacts of level-II charging [5]; however, this requires an extensive communication system to be adopted.

In general, both levels-I and II require single phase power sources with on-board vehicle chargers. On the contrary, three-phase power systems are used with off-board chargers for level III fast charging rates (50-75 kW). The use of fast charging stations significantly reduces the EV charging time to less than half an hour for a complete charging cycle . Additionally, a widespread deployment of fast EV charging stations across the urban and the residential areas would eliminate the EV range anxiety concern [6-7]. However, the high power charging rates required over a short interval of time for level-III impose a high demand on the electrical grid [8-9].

The current grid infrastructure is not capable of supporting the desired high charging rates of level-III. Thus, achieving fast charging rates while solely relying on the electrical grid does not only require the improvement of the charging system, but also the improvement of the electrical grid capacity. Additionally, drawing large amounts of current from the electrical grid will increase the utility charges especially at the peak hours and consequently will increase the system cost.

II. ELECTRIC VEHICLE AND TECHNOLOGY

Introduction

An **electric vehicle**, also called an **EV**, uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or an electric generator to convert fuel to electricity. EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

History of Electric Vehicle

]In the late 1890s Electric Vehicles (EVs) outsold gasoline cars ten to one. EVs dominated the roads and dealer showrooms. Some automobile companies, like Oldsmobile and Studebaker actually started out as successful EV companies, only later did they transition to gasoline-powered vehicles. In fact, the first car dealerships were exclusively for EVs.

In the late 1960s and early 1970s, there was a rebirth of EVs prompted by concerns about air pollution and the OPEC oil embargo. In the early 1990s, a few major automakers resumed production of EVs – prompted by California 's landmark Zero Emission Vehicle (ZEV) Mandate. Those EVs were produced in very low volumes – essentially hand-built like their early predecessors. However, as the ZEV mandate was weakened over the years, the automakers stopped making EVs – Toyota was the last major auto maker to stop EV production in 2003. Thanks to the efforts by DontCrush.com some of these production EVs were saved from the crusher.

What Is EV

An Electric Vehicle (EV) has a battery instead of a petrol tank, and an electric motor instead of an internal combustion engine. The electricity stored in its battery powers the electric motor. When too low, the car's battery needs to be recharged by plugging it in to use grid electricity, like when your phone needs charging. Similarly, Plug-in hybrids (PHEVs) come with a plug socket and charging leads so that you can charge the battery via the mains. Although they have a smaller capacity, these models are able to run in electric-only mode for 20-30 miles

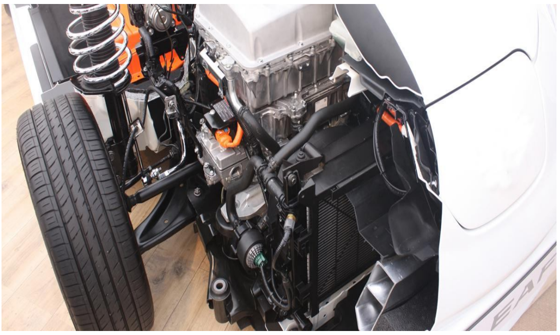


Fig. 1 Battery electric vehicle

Lots of models, such as the Nissan Leaf, turn off the engine when stopped, and actually charge the battery when you brake – this is called 'regenerative braking'. This technology is also seen in hybrid models and it helps to power the electric motor without needing to plug it in to charge so you can go further without using the petrol engine

Types of EV

There are three main types of electric vehicles (EVs), classed by the degree that electricity is used as their energy source. BEVs, or battery electric vehicles, PHEVs of plug-in hybrid electric vehicles, and HEVs, or hybrid electric vehicles. Only BEVs are capable of charging on a level 3, DC fast charge.

Battery Electric Vehicles (BEV)

Battery Electric Vehicles, also called BEVs, and more frequently called EVs, are fully-electric vehicles with rechargeable batteries and no gasoline engine. Battery electric vehicles store electricity onboard with high-capacity battery packs. Their battery power is used to run the electric motor and all onboard electronics. BEVs do not emit any harmful emissions and hazards caused by traditional gasoline-powered vehicles. BEVs are charged by electricity from an external source. Electric Vehicle (EV) chargers are classified according to the speed with which they recharge an EVs battery.

The classifications are Level 1, Level 2, and Level 3 or DC fast charging. Level 1 EV charging uses a standard household (120v) outlet to plug into the electric vehicle and takes over 8 hours to charge an EV for approximately 75-80 miles. Level one charging is typically done at home or at your workplace.

Level 1 chargers have the capability to charge most EVs on the market.
Level 2 charging requires a specialized station which provides power at 240v. Level 2 chargers are typically found at workplaces and public charging stations and will take about 4 hours to charge a battery to 75-80 miles of range.
Level 3 charging, DC fast charging, or simply fast charging is currently the fastest charging solution in the EV market. DC fast chargers are found at dedicated EV charging stations and charge a battery up to 90 miles range in approximately 30 minutes.

Plug-in Hybrid Electric Vehicle (PHEV)

Plug-in Hybrid Electric Vehicles or PHEVs can recharge the battery through both regenerative braking and “plugging in” to an external source of electrical power. While “standard” hybrids can (at low speed) go about 1-2 miles before the gasoline engine turns on, PHEV models can go anywhere from 10-40 miles before their gas engines provide assistance.

Hybrid Electric Vehicles (HEV)

HEVs are powered by both gasoline and electricity. The electric energy is generated by the car’s own braking system to recharge the battery. This is called ‘regenerative braking’, a process where the electric motor helps to slow the vehicle and uses some of the energy normally converted to heat by the brakes.

HEVs start off using the electric motor, then the gasoline engine cuts in as load or speed rises. The two motors are controlled by an internal computer, which ensures the best economy for the driving conditions.

Block Diagram and Description

This dissertation consists of PV system, power grid, dc to dc converter, ac to dc converter, battery charging circuit, battery, EV charging circuit and load. PV system generates dc supply which is further boosted by dc to dc converter section. Battery is charged through battery charging circuit which receives supply from solar system and power grid. Electric vehicle charging circuit is used here to charge EV vehicle. AC supply of power grid is converted as dc by ac to dc converter section. When Solar power failure then that time Grid supply is connected to the load through the auto switching device.

PV System:

A photo-voltaic system, also PV system or solar power system, is a power system designed to supply usable solar power by means of photo voltaics. Simply put, PV systems are like any other electrical power generating systems, just the equipment used is different than that used for conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same, and are guided by a well-established body of electrical codes and standards.

Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute, and store the energy produced by the array.

Power Grid:

An electric grid is a network of synchronized power providers and consumers that are connected by transmission and distribution lines and operated by one or more control centers. When most people talk about the power "grid," they're referring to the transmission system for electricity.

DC to DC Converter:

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission).

AC to DC Converter:

The ac to dc converter converts the ac input into the dc output. Average power is transferred from an ac source to a dc load. The ac to dc converter is called as rectifier. The peak inverse voltage is the maximum reverse voltage to which the diode is subjected when it is non conducting.

Battery Charging Circuit:

A battery charger, or recharger, is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it. A trickle charger provides a relatively small amount of current, only enough to counteract self-discharge of a battery that is idle for a long time.

EV Charging circuit:

EV charging circuit is designed to charge electric vehicle.

Software Requirements:

- Matlab 20172 or Higher Version.
- Simulink Tool Box.
- OS – WINDOWS 7 or Higher Version.

Minimum Hardware Requirements Of PC:

- Processor – Intel 1.5 Ghz , 32 bits.
- RAM – 2 GB
- Hard disk – 100 GB
- Monitor Screen Size – 15 Inch
- Keyboard
- Mouse

III. SIMULATION AND RESULT DISCUSSION

Introduction

In this chapter of dissertation I am going to design the model of Electric vehicle and its charging system. In this chapter I will also show the results of simulation system of electric vehicle charging and its importance. By using the MATLAB version 2014b, I designed the simulation model in which supply from solar system and grid system is given. At a time, only one mode of supply is given initially I start from solar system which gives a voltage rating of 415 Volt as output Voltage and 200 Amp as Output Current which is given to RL Load.

Simulation Model

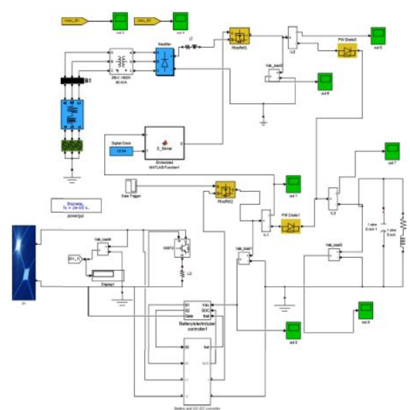


Fig. 1 Snapshot of Simulation Model of Electric Vehicle

Major Components of Electric Vehicle

In this section I will discuss the major components of Electric Vehicle are

1. Solar system
2. Battery and DC-DC converters
3. Grid System

Solar System

In this section I will design the simulation model of solar system in MATLAB which is composed of MPPT voltage, irradiance constant, two converters, freewheeling diode and scope block to show their outputs.

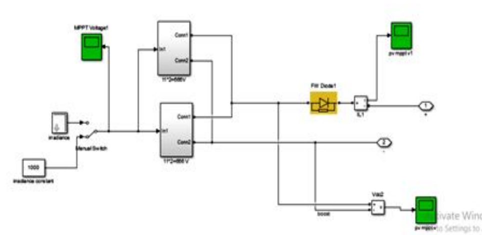


Fig. 2 Simulink Diagram of solar system

Battery and DC to DC Converters

The simulink diagram of Battery is shown below in fig 5.2. This block consist of IGBT, Freewheeling diode and State of changing component, voltage, current rating, Battery Components, Low pass Filter and scopes for their output representation. The parameter of battery is shown below. The battery type used is nickel metal hydride battery nominal voltage of battery is 400V and rated capacity is 50 AH.

Table 5.1 Show The Parameters Used For Battery

Sr.No	Parameters	Rating
1	Battery Type	Nickel Metal Hydride (NIMH)
2	Nominal Voltage (V)	400 V
3	Rated Capacity (AH)	50 AH
4	Initial State of Charge %	60 %
5	Maximum Capacity (AH)	53.84 AH
6	Fully Charged Voltage (V)	471.18 V
7	Nominal Discharge Current (A)	10 A
8	Internal Resistance (Ohms)	0.08 Ohm
9	Capacity Ah @ Nominal Voltage (V)	48.07 Ah

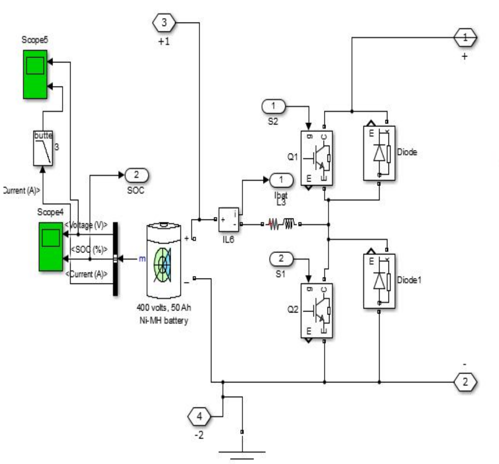


Fig. 3 Simulink diagram of Battery

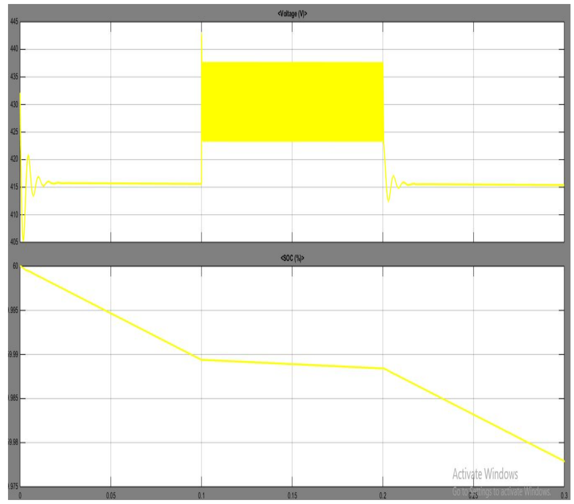


Fig. 4 Simulink result of nominal voltage and SOC of Battery used.

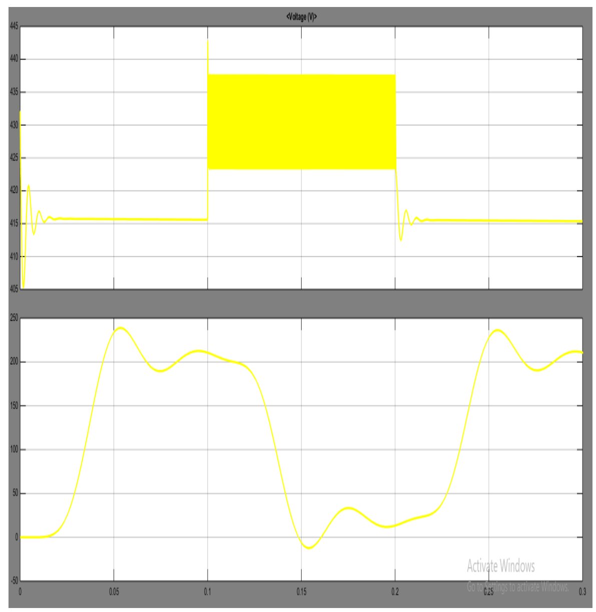
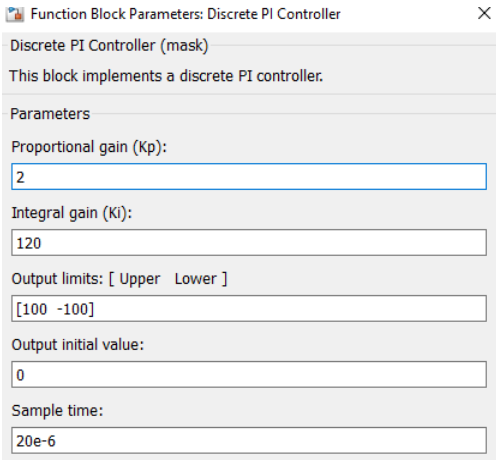


Fig.5 Simulation result of Nominal voltage and current of Battery.

Controllers used for controlling the charging of battery:

In this simulation model I make the simulink diagram for controlling the charging of battery using PI controller. The PI controller holds good for this kind of work. The parameters of PI Controller are

Table Parameters of PI Controller



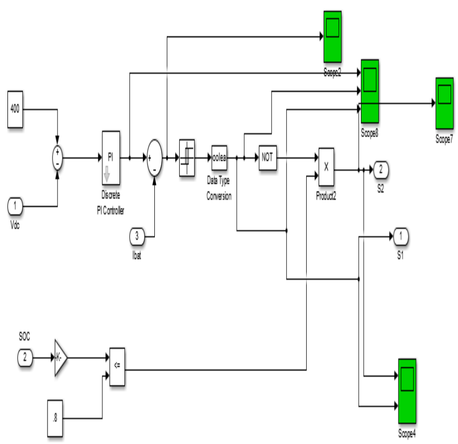
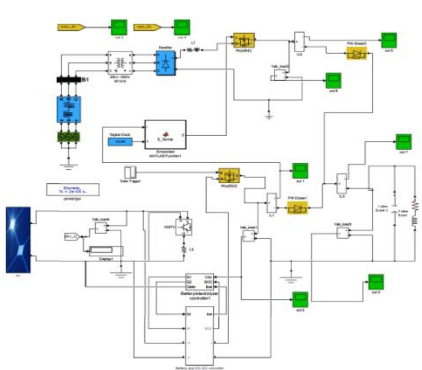


Fig. 6 Simulink diagram of PI Controller based on SOC of battery

Simulink Model of PV fed Grid Charging System

In this work I will work on solar fed grid charging system. In the work, simulink model start from solar system after few minutes it will switched to grid supply system when solar not available (during night hours) and then returned to solar system. This is the working methodology of proposed system. In this model R-L load is taken.



This is the Solar fed/ Grid charging system of electrical vehicle. In this model I will used embedded MATLAB function in connection with MOSFET for switching of Solar to grid and then reversed back.

The current and power outputs of solar panels are approximately proportional to the sun’s intensity. At a given intensity, a solar panel's output current and operating voltage are determined by the characteristics of the load. If that load is a battery, the battery's internal resistance will dictate the module's operating voltage.

A solar panel which is rated at 17 volts will output less than its rated power when used in a battery system. That’s because the working voltage will be between 12 and 15 volts. Because wattage (or power) is the product of volts multiplied by the amps, the module output will be reduced. For example, a 50-watt solar panel working at 13.0 volts will products 39.0 watts (13.0 volts x 3.0 amps = 39.0 watts). This is important to remember when sizing a PV system.

An I-V curve is simply all of a solar panel's possible operating points (voltage/current combinations) at a given cell temperature and light intensity. Increases in cell temperature increase a solar panel’s current slightly, but significantly decrease voltage output.

Working of Electric Vehicle Charging Model

In this section I describe the working of solar fed Grid charging system of Electric vehicle. Initially the vehicle is charged from solar from time 0.1 to 0.2 minutes, after that a time comes when solar not available or due to weather condition or battery going to discharge or some other reason. At that time with the help of Embedded MATLAB function and MOSFET supply of charging system is switched to Grid system where the voltage of 400 volts and 200 amps as output of the system. The simulation time for which system is set to 0.2 to 0.3 minutes and then reversed back.

Currently Electric Vehicle charging system is mostly based on Grid supply system. But I want to change to this charging system to solar system which can be rechargeable.

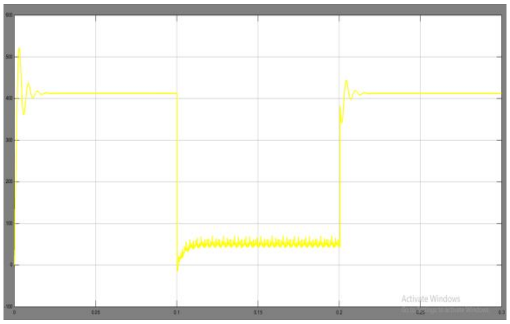


Fig. 7 Simulation result of voltage when connected to solar system

In this figure simulation start from 0 to 0.1 point when connected to solar system gives output and gives less than 50 voltage when Connection from grid is not given at that time current is zero so this is called reverse effect and from point 0.2 to 0.3 again voltage continues to 400 volt. Current rating given by solar is given below

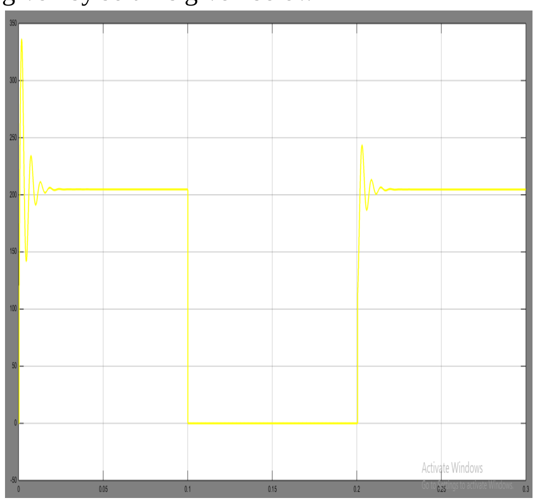


Fig. 8 Simulation result of current when connected to solar system

In this figure simulation start from 0 to 0.1 point when connected to solar system gives output and gives less zero current when Connection from grid is not given so this is called reverse effect and from point 0.2 to 0.3 again current continues to 200 Amp.

GRID Connected charging EV

In grid connected system I will use 3 phase supply for giving supply to electric vehicle. Generators give 415 Volt to supply system and given to RL Load through Busbars and Transformer by 400 Volt to the charging system. The supply voltage and current waveform is shown below.

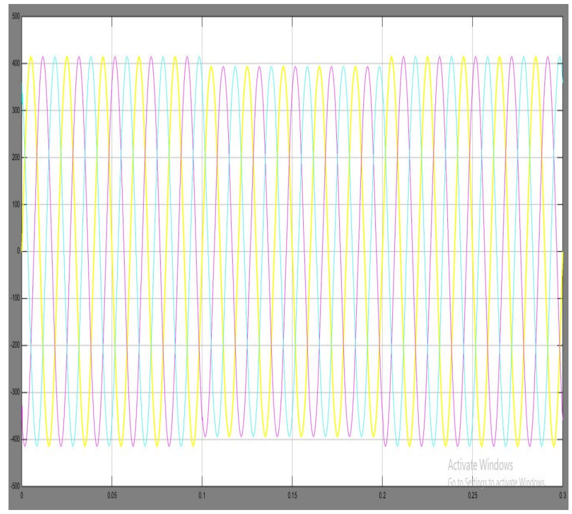


Fig. 9 Simulation result of Supply Voltage when connected to Grid supply system

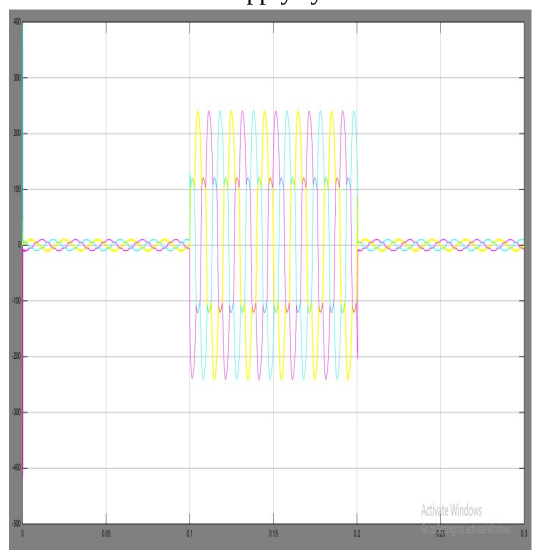


Fig. 10 Simulation result of Supply current when connected to Grid supply system

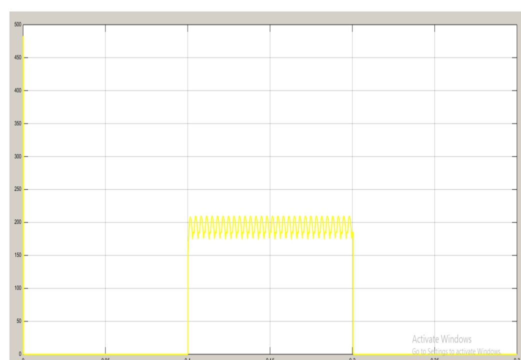


Fig. 11 Simulation Result of Current outputs of grid connected supply system

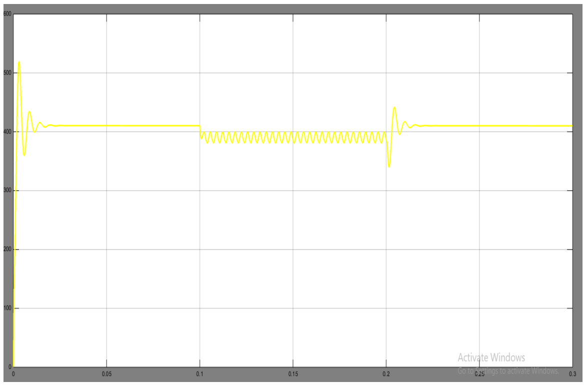


Fig. 12 Simulation result of Output Voltage when connected to supply Grid system

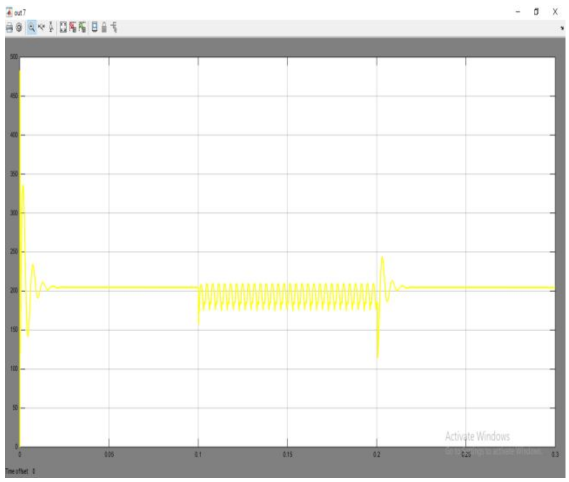


Fig. 13 Simulation result of output voltage when connected to solar supply system

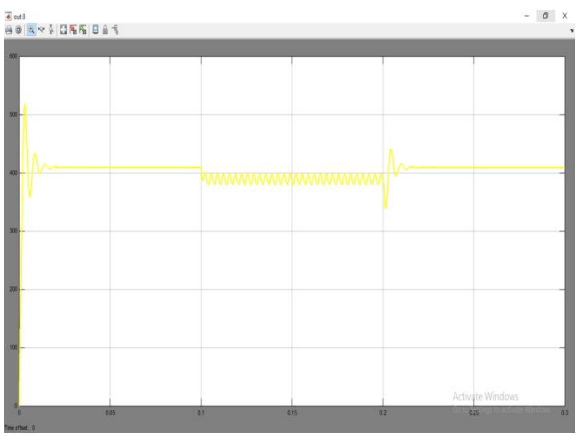


Fig. 14 Simulation result of output voltage when connected to solar supply system

IV. CONCLUSION

Solar based electric vehicle charge system has been designed and tested in MATLAB simulink tool successfully. MATLAB version 2017a is used for designed. AC source charger also designed and it will support whenever solar side power failure occurred. Embedded based function calling automation is used here for auto switching process (solar mode/AC Source Mode). A proposed technique for PV-battery powered EV fast charging stations is presented in this work. The broad objective of the proposed technique is to help the penetration of the PV/battery systems into the grid and to support the growing need of fast EVs charging rates.

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