DYNAMIC CHARGING OF ELECTRICAL VEHICLES FROM PHOTOVOLTAICS IN THE PARKING LOTS USING FUZZY LOGIC

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CERTIFICATE

We accept the work contained in this report as a confirmation to the required standard for the partial fulfillment of the degree of MS (EE).

Head of Department

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Dedication

Thanks to Almighty Allah, I dedicate this work to my Parents, Brothers, my Wife, my Daughter and whole Family the most admirable and lovable people in my life.

DECLARATION OF AUTHORSHIP

I hereby acknowledge that this thesis is my own work and contains no materials previously submitted for a degree or diploma in any institution or university of higher education. To the best of my knowledge, it contains no material previously published or written by another person except where due reference is made in the text; or contain any defamatory material.

Student's Signature: ________________________

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Abstract

Renewable sources of energy is getting more attention currently for sustainable environment. The clean energy sources contribute extensively in the mitigation of harmful emission and climate change. To fulfill this demand, transportation electrification is the need of time. In order to decarbonize the transport sector Electric vehicles (EVs) demand has increased globally. It is proposed that by 2040, there will be 35- 47% Electric Vehicles on the roads. However, the EVs' growth is contained by one of the main hindrance i.e. the longer charging time. Due to this, burden on electrical grid will definitely rise. To cope with this obstacle, an alternative source of energy and an appropriate system of charging is necessary to develop. Photovoltaic in the parking lots of working places is the most feasible solution to this problem. Because the cars remain parked in the parking lots for most of the time.

This work proposed the possibility of developing a charging technique for EVs on priority basis using solar energy. The main problem with solar panels is the variation in output power because the solar insolation does not remain the same throughout the day. The dynamic charging technique is proposed that will charge the EVs on priority using the available amount of output power. This design presents a PV connected charging mechanism for EVs which uses two control variables, SOC of battery and the duration of stay in charging station, easy to apply lacking the need of exhaustive modeling. Suggested mechanism is entirely simulated in MATLAB/Simulink and FIS is used for the design and selection of rules for FLC to analyze the charging system characteristics and behavior. To ensure the practicability of designed technique the simulation results are analyzed.

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ABBREVIATIONS

RE	Renewable Energy
DG	Distributed Generation
PV	Photovoltaic
IEA	International Energy Agency
EU	European Commission
ESS	Energy Storage System
DC	Direct Current
AC	Alternate Current
VSC	Voltage Source Converter
BEV	Battery Electric Vehicle
EV	Electric Vehicle
PEV	Plug-in Electric Vehicle
LED	Light Emitting diode
PCC	Point of Common Coupling
EVCI	Electric Vehicle Charging Infrastructure
CS	Charging Station
SPWM	Sinusoidal Pulse Width Modulation
MPPT	Maximum Power Point Tracking
SOC	State of Charge
SOH	State Of Health
DOD	Depth of Discharge
PI	Proportional Integrator
PID	Proportional Integrator & Derivative

FLC	Fuzzy Logic Control
FIS	Fuzzy Inference System
FCS	Fast charging station
CCVV	Constant current variable Voltage
CCCV	Constant current Constant Voltage

Chapter 1

Introduction

CHAPTER 1. INTRODUCTION

1.1. INTRODUCTION:

Even today the world mostly relies on fossil fuel to fulfill its energy requirements. The energy produced by burning fossil fuel is very much advantageous, but at the same time it is responsible for the emission of hazardous and toxic gases. Apart from this the resources are depleting very rapidly. The main two sectors which consumed tremendous amount of fossil fuel are electricity and transportation. The electricity share in energy consumption was less than tenth in 1973 and it grew immensely, currently it is approximately a fifth and it might reach about a quarter by 2040[1]. The electricity generation is mainly from fossil fuel (68%) and concern over its source of generation is rising [2], it makes the power sector responsible for growing emissions of environmental unfriendly gases. It is very important to contain these emissions to hold climate change[3].

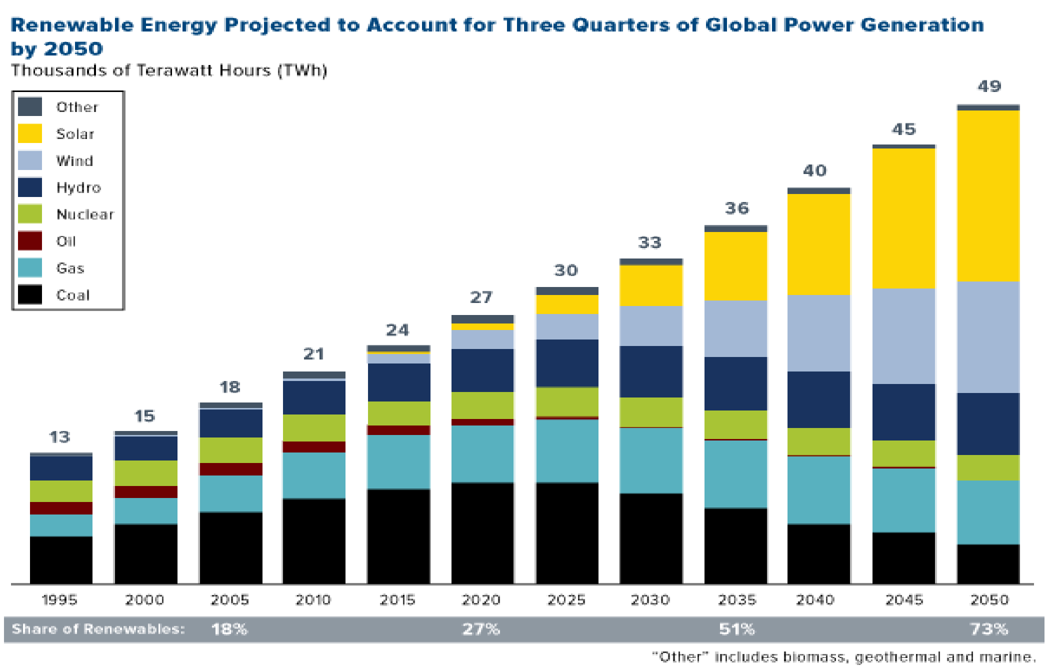

Figure 1. 1 Expected share of renewable energy up to 2050[4].

Energy produced from sustainable sources is seen as the best solution for both the problems the increasing demand of electricity and environmental sustainability. There are different types of renewable energy which includes all types of energy resources which do not deplete or the source recycles. The figure 1.1 shows the world will mostly switch to renewable energy by 2050.

The renewable energy RE share was 18.9 % of energy consumed in the EU and is on a way to achieve the 2020 target of 20%. Europe is trying hard to become the first environmental friendly region globally by 2050 and it is the primary objective behind the European Green Deal, which will enable European people to benefit from sustainable green energy[5]. Germany in the first six months of 2018 generated sufficient power to power every home in the state for a year. The country is on the way to achieve the target to produce 65 percent of their electricity from renewable sources by 2030. Germany is looking for a bright future with solar energy despite of being relatively cloudy country. Island uses geothermal energy for almost all the energy requirements. Sweden has also set the target of removing fossil fuel from electricity generation by 2040 and is investing in micro grid, solar and wind energy. The world's largest carbon emitter country China will also generate 35% of its electricity from renewables by 2030 and cleaning up its contaminated air. In 2017 United States was able to generate 18% of all electricity by renewables which includes solar energy, wind and hydroelectric energy[6]. Almost every country of the world is trying to leave the traditional way of producing electricity and switch to renewable energy resources.

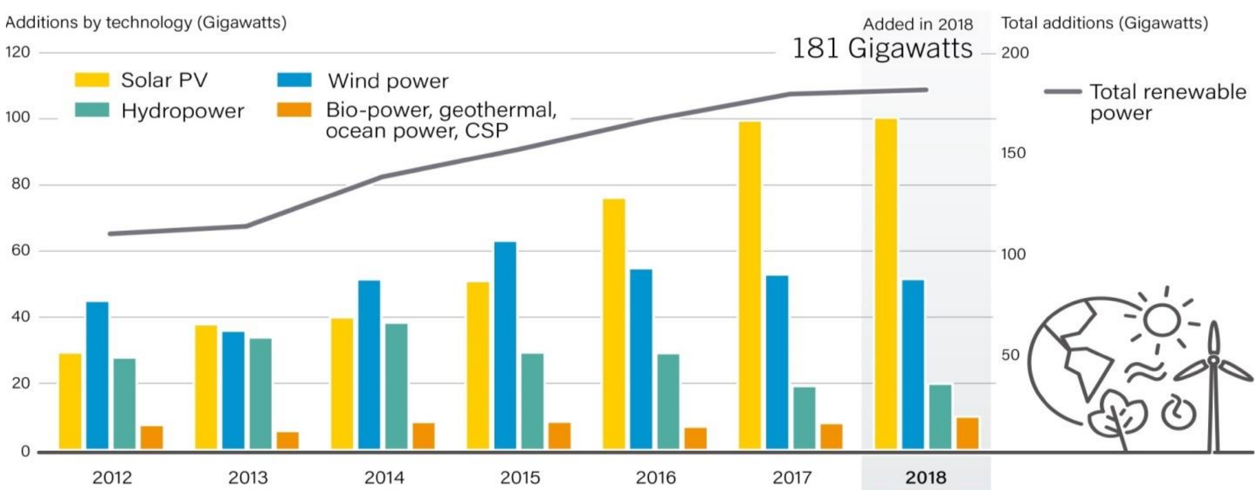

Figure 1. 2 Renewable Energy share in global energy production.

The figure 1.2 shows that the world has invested more in the solar energy than any other renewables. Because, among them the solar energy is more economical and convenient to be used at present time. In a decade the PV panels cost have plunged by the factor of 10.

The amount of solar power which reaches the earth's surface is considerably large 121,800 TW[7], which in one hour is approximately equal to the energy spent by human on all activities in one year. Coal utilization dropped by almost two hundred million tons (Mt) or 1.3%, as a result emission also reduced as compared to previous recorded value two years back in 2018. Developed countries noticed drop in emissions to great extent [8]. This happened because of the decreasing price of solar photovoltaic (PV) which is very helpful in encouraging the role of this technology.

1.2. Electric Vehicles:

Another sector which needs to be decarbonized is transport sector. The emission from this sector has great effect on environment and it is intrigue to be reduced greatly if this sector to be decarbonize. Environmental policies endorses the use of energy having less carbon share[9]. About a third of total energy is consumed by transport sector; almost petroleum based and is responsible for about a one by four for emissions. To decarbonize this sector, the most appropriate way is to replace the conventional vehicles with Electric vehicles EVs. Transportation electrification is the need of time to hold the climate change and preserve the conventional energy resources[10]. The electric vehicles (EVs) are much more energy efficient and clean when charge by renewable energy sources. For clean environment it is suggested that EVs should widely be adopted[11].

1.2.1. EVs Market Penetration:

The EVs' penetration in the market at present is low due to few problems associated with them, but it is significantly increasing day by day. This will be accomplished by overcoming the conventional bottlenecks which are short driving range, high price and the unavailability of appropriate charging infrastructure. The first two problems are related to the battery, charging infrastructure refers to availability of charging point and types of charging especially fast type charging, which is a challenge at present. To overcome the bottleneck like short driving range of the battery capacity is increasing which allows the vehicle to cover long distances.

For instance Nissan has upgraded its Leaf model's battery which can travel 250Km per charge, 26% more than the prior model[12]. The new version of Nissan has the capacity to travel 226miles on maximum charged battery. The company has accomplished the task of fitting larger battery pack by eliminating extra covered free space using modern welding technique[13]. 14 % decrease have been noticed in the price of lithium ion battery. Charging points at various positions should be constructed to avoid inconvenience. The charging station can be designed taking power from wind and solar panels. The parking could be transform into charging stations by using photovoltaic which gets energy directly from sunlight.

Figure 1. 3 Solar parking for EVs charging

The amount of moving electric cars on road will reach 125 million by 2030 [14]. Electric vehicles penetration has been increased enormously in the last few years, two years back the figure of passenger electric vehicles was 50 lac in 2018, more than 60% increase from the figures issued in 2017. Approximately half of the electric cars in 2018 were on the roads of China, a quarter share has Europe and slightly less than quarter electric vehicles approximately 22% are moving on the roads of USA.

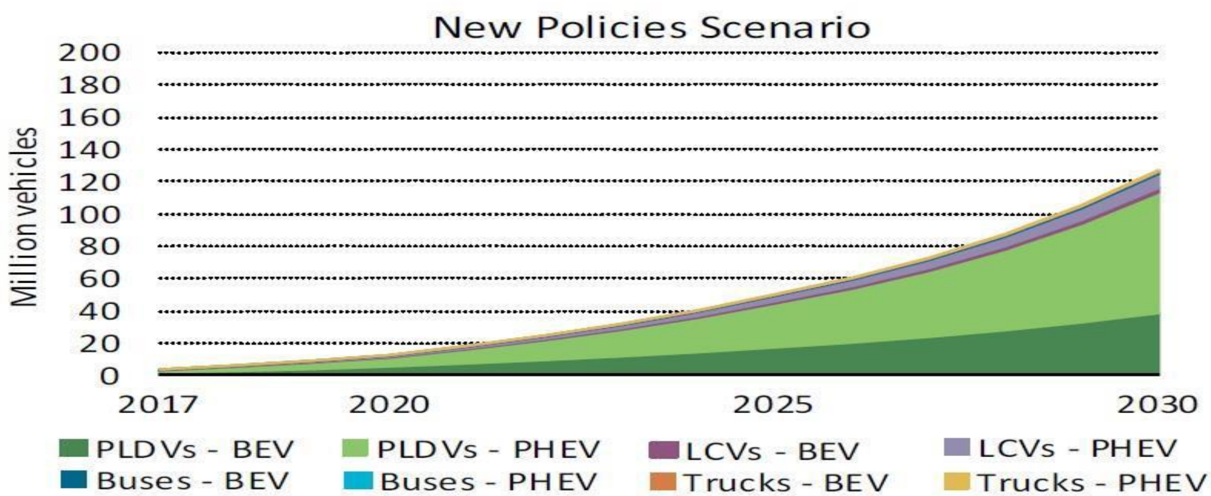

Figure 1. 4 Global EV stock by scenario, 2017-2030[15]
Note: PLDVs = passenger light duty vehicles; LCVs = light commercial vehicles

1.3. Problem Description:

The EVs can be recharged from the system at any place, but it would be more comfortable for EVs' users to install Photovoltaic at the parking lots for EVs charging. The system could be designed for residential, commercial and working places parking lots, because the cars remained parked there for long time. But the power generated by the PVs is intermittent, does not remain same. The variation in the output power occur due to the varying solar irradiance because it does not remain same throughout the entire day. Changes in environmental temperature during day time also affects the PVs output power. To overcome the power intermittency for EVs charging becomes a challenge. For this an effective control technique needs to be designed which will organize the system in a way to charge a number of EVs dynamically according to insolation.

The dynamic charging technique will charge the batteries on priority basis considering the parking duration of cars and SOC of the batteries.

1.4. Objectives:

The main aims of this exploration work are as under:

- To propose a charging technique for electrical vehicles charging with buck DC/DC convertor powered by photovoltaic.
- To design a control technique with Fuzzy Logic Controller (FLC) to charge the EVs on priority basis according to SOC of the batteries and the parking duration of EVs.
- To propose a dynamic charging method on the basis of batteries SOC and parking duration of EVs.

1.5. Thesis Organization:

Organization of the this thesis has been done in the following manner.

Chapter ‘1’ highlights the adoption of renewable energy sources and their advantages. EVs’ historical background, market penetration, bottlenecks in adoption, battery types and charging procedures are discussed in this chapter. The future of EVs and the constraints in its way are discussed.

Chapter 2 explains the detail summary of the literature work on PVs and EVs. The RE integration for charging EVs and the challenges are studied. Moreover different control techniques used for charging the batteries are discussed in this chapter.

Chapter 3 has well explained the necessary mathematical calculation and equations of the problem for control. The proposed model simulation has been done in MATLAB/Simulink. Fuzzy logic control approach ensures battery charging according to priorities.

Chapter 4 provides the real-time simulation results of the designed work. The outcomes endorse that the suggested control method is quite effective because of its strong response.

Chapter 5 shows the conclusion and future work extension of the proposed thesis work.

Chapter 2

Literature Review

CHAPTER 2. LITERATURE REVIEW

The development of related theoretical foundation is very significant for each research before collecting data[16]. The idea of electric vehicles, battery technologies, EVs' charging methods, charging infrastructure, renewable energy especially PVs integration with EVs system are focused by the selective reviews.

2.1. Electric Vehicles (EVs):

In 1830 after the invention of motor which was first dc powered motor the EVs were introduced as well to use as a replacement for horses and buggy. EVs didn't become a feasible choice at that due to lack of rechargeable batteries till the Frenchmen Gaston Plantae and Camille Faure introduced and upgraded the potential of batteries in 1881. In the start of the 20th century EVs saw their golden time, approximately half of the cars sold in America were EVs[17]. Though the ICEV at that time were of better consideration as compared EVs for their short driving limit coercing them aside of the competition, due to which the electric vehicles was abandoned for a long time.

2.2. Battery technologies of Electric vehicles:

The main hindrance in improvement and market penetration of EVs are the potential of batteries and energy storage capacity of BEVs. A battery charges through a charger defines the performance of an EV. It is very crucial to design a battery properly for smooth performance. Electrical, electro-chemical and mathematical models of batteries are discussed in[18].

2.2.1. Battery Types for EVs:

The lithium ion battery (Li-B) defined as the most suitable type of battery for EVs as compared to other kinds of batteries[19]. The life duration, charging rate, storage capacity, temperature and safety of a battery have relation with the approach used for battery charging[20].

The constant current/constant voltage approach is the common technique for charging Li-ion battery. Refilling of ICEV with gasoline takes very little time while it takes much longer time to charge a BEV, therefore for short charging time and improve efficiency fast and quick charging techniques are suggested[21]. The gap between conventional ICEVs and EVs can be bridged by improving the charging speed. For this a special design of a battery is required to endure (UFC) and it is very problematical to design such type of complex battery. UFC also reduces the battery's useful life. The fast charging strategy also demands a battery design which could withstand high current[22]. Charging abilities of different electric chargers on different types of BEVs are shown in the table.

2.2.2. Battery Size for EVs:

The battery size is important and necessary thing to be kept in view for the design of EVs. Its size varies with the size and type of BEVs The batteries' sizes which have ratings from 20-100 kWh are used for light-duty BEVs (LDBEVs). The battery size is also a major hindrance in EVs' growth. It is obvious the battery with large capacity of storage will provide more charge to cover long distances, but the extra battery's weight will decrease EV's performance[25]. Hence, reducing the battery mass while growing it is capability means to focus on energy efficiency and power density

2.2.3 Battery life of EVs:

A lot of literature about the battery Cycle life of EVs is present which have addressed the factors likes surrounding temperature, material type and charging depth[26]. The charging capacity of the battery declines as it reaches to the long cycle life and life of the battery is associated with charging rate. The fast and ultra-fast charging UFCH strategies reduces the battery life substantially. Therefore the slow and normal charger is more economical than fast and ultra-fast charging technique[27].

2.2.4. EVs Battery price:

When it comes to price the total price of EVs is greatly affected by the battery prices because they are very expansive. The International energy agency suggests the electric vehicles users should pay less than 330 US dollar per Kwh. The prevalent market rates of batteries are taking EVs market to the negative side. The batteries' cost should be controlled for the IEA objectives to be accomplished [28].

2.3. EVs charging structure and methods:

It is vital to develop proper charging infrastructure for BEVs to eliminate acceptance barriers. This will increase the EVs' fleet too considerable amount because it would become easier to recharge the car.

2.3.1. EVs Charging Infrastructure :

The existing EVCI development plans are linked to expected number of EVs and various research works have been done on the charging infrastructure of EVs [29].The charging setup expansion is reliant on people demand. A larger charging flexibility exists for EVs by using various electric outlets[29]. For execution of EVCI in cities the traffic flow map ought to be studied [30]. The availability of charging station is notably linked to EVs' satisfaction because drivers desire not to travel more than five minutes' drive to facilitate from a charging points, hardly few drivers on board travel for more than a quarter of hour to recharge[31]. The execution of EVCI refers to the addition of various types of EV charging points[32]. The CS has been classified to 3 types level wise which are 1 to 3, by the "Society of Automotive and Engineers"[33]. The first type uses less voltage and ampere values, no need to install a new network because it is very common charging system. The second type's specification is a bit higher in ampere's value than the prior the voltage remain the same i.e 220 V AC and 20A. The third type level 3 is called fast charging with high voltage of 480 V AC. It needs a specific network and proper measurement of safety[28]. A battery essentially be designed which could endure large current for fast charging. The fast charger ought to be used at the constant current stage, the first stage. The current must be decreased when the battery grasp a good state of charge to prolong battery life cycle and protect the circuit[27]. Comparatively shorter time duration is needed for charging with the ultra-fast charger with the output power of

200 KW and beyond. This type of charging effects the distribution network greatly, like the short circuit level rises, voltage drops because enormous sum of reactive power is consumed and reduction in transformer life cycle[34].

The high power connection can jeopardize car and also reduce battery lifespan, since most of the EVs cannot bear supercharger. Power output of 120 kW from a supercharger was tolerated by Tesla in 2017 exhibiting the ability of accepting a rapid charge, measured the maximum output noted for vehicles batteries charging so far[24]. The fast charger are suitable to install alongside long route for the public to get benefited in short time[35]. Still, extensive improvement is essential in EVs' charging structure. EVs can become more easy to use by reducing the charging duration[36]. The use of fast DC and constant current (CC) charging method reduces the charging duration to great extent[37]. DC fast charging of two levels according to the international standard of IEC 61851-1 has been described by the author in[38]. A grid-tied charging park with real-time energy management algorithm (RTEMA) is designed in[39]. The PVs are also integrated with the charging park. The fuzzy controller is used by the designed algorithm to manage the state of charge (SOC) of PHEV's batteries on arrival for charging and their charging or discharging duration. The constant current charging mode could be utilized as well for determination of charging power need, built on battery volume, leaving time, coming time and the battery SOC. In [40] PV controller scheme and controlling technique of buck and boost battery charger is studied. The bang-bang fuzzy logic controller is employed for the EV charging. The constant current method off charging is used and the controller is intended to charge the photovoltaic batteries. The resistor is used in place of battery and DC voltage source as PV panel.

Chapter 3

Methodology

CHAPTER 3. METHODOLOGY

3.1. PV System Modeling:

PVs' economical price has revolutionized the use of alternative energy and is on the way to new heights. It has brought numerous opportunities for investors because it has initiated massive transformation from conventional resources to renewables. PV is a semiconductor device which uses sunlight to alter natural light energy into DC Electrical Energy. When sunlight strikes the solar cell the electron releases from the atom which leaves a hole behind. This hole is filled by another one and so on. The hole pair generate which gives rise to free electrons.

3.2. Basic solar cell Design:

A cell is designed when a resistance i.e Rs is coupled with a parallel arrangement of a current source in series having one Diode. When sunlight falls on solar cell the solar cell transform sunlight into electrical using photoelectric effect. Power produce by PVs is intermittent because it depends on solar irradiance. The output power of the PV module decreases with the decrease in light intensity and vice versa. The power can be consumed power by attaching exterior load. Equation which are necessary to mention prior to the solar cell design are as under.

Equation of Thermal voltage:

$$V_T = k_B T_{OPT} / q \qquad (3.1)$$

Equation of diode Current:

$$I_d = NpIs[e^{(V/Ns)+(ir_s/n_s)/NV_t C} - 1] \qquad (3.2)$$

Equation of I load:

$$I_L = Iph\,N\,p - I_d - I_{SH} \qquad (3.3)$$

Equation of shunt current:

$I_{SH} = (I R_S + V)/R_{SH}$ (3.4)

Equation of reverse saturation current:

$$I_S = \left[I_{RS} \left(T_{OPT} / T_{REF} \right)^3 * q^2 Eg / Nk_B * e^{(1/T_{OPT} - 1/T)_{REF}} \right]$$ (3.6)

Equation of reverse current:

$I_{RS} = I_{SC} /[e^{(qv)} OC^{kCT} OPT - 1]$ (3.7)

Equation of power:

P= I.V (3.8)

The letter used depicts the following,

V_T is thermal voltage

V is operating voltage

V_j is junction voltage

Is is diode reverse saturation current

Isc is short circuit current

I is output current of cell

T_{REF} is cell's reference operating temperature

T_{OPT} is cell operating temperature

R_{SH} is cell shunt resistance

Rs is cell series resistance

N is factor of ideality

k_B is Boltzmann constant

q is the amount of charge on electron

Ns are the number of cells in series

Np are number of cells in parallel

G is irradiance

Behavior of a under consideration cell is considered as building blocks for the development of solar panels. Source of current and diode is used to design an ideal cell

The construction of solar cell considers standard test condition with values of coefficients equivalent as the aforementioned one. The figure below shows the PV equivalent model.

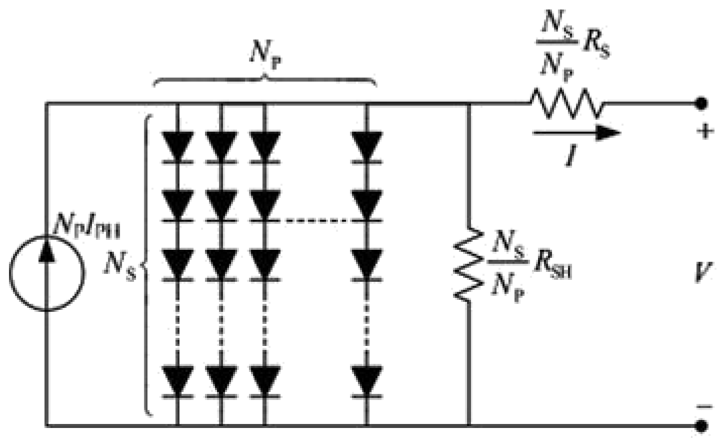

Figure 3. 1 PV Equivalent Model Solar Cell.

3.3. Battery Terminologies:

Battery is a common energy storage device which stores electrical energy in the form of chemical energy. Batteries consist of different types like battery, using different types of chemicals and metals. Li-ion batteries are most commonly used battery in Electric vehicles.

3.3.1. Ampere hour (Ah):

Ampere hour is the unit of electrical charge and it denotes the charging capacity. This is represented by Ah. If volume of a Battery is 1 Ah it can support current flow of one ampere for an hour. The same battery will discharge is twenty minutes for a current of 3 ampere and will discharge in two hours for 0.5 ampere current.

3.3.2. C-rate:

It determines how quickly the battery will run out of energy. At one C the charging of one Ah battery indicates that the current at which it can charge is 1A. The battery will charge exactly in an hour if losses are ignored. It work exactly in the same manner for higher c values. C-rate is very important when it comes to the selection of a battery for different purposes. The table below indicates the C-rate and service times of charging and discharging a 1Ah battery.

3.3.3. State of Charge:

The SOC determines that how much charge is present in battery. SOC describes the present state of battery expressed in percentage. The SOC give information to the user that how much time the battery will perform before it needs to be recharged. The SOC determination is very important because knowing the remaining capacity of the battery will help in designing control strategies.

3.3.4. SOH:

SOH of a battery is present condition of battery as compare to the ideal condition. The SOH of a battery might be 100% at manufacturing time but it declines with the use and time. When SOH drops below 80% then the battery is in queue for replacement.

3.3.5. DOD:

The DOD means, how much batteries have discharged. If a battery has charged to hundred percent then its DOD is 0%. If it delivers 40% energy and SOC charge is 60% then its DOD is 40%. The DOD is inverse of SOC. The DOD means how much percentage of energy is delivered. Usually a battery will not be discharged to 0% and it is also not recommended because it reduces the life of battery.

3.3.6. Life Cycle of Battery:

Batteries performance are reduced with the usage over time. The life cycle means when the serviceable cycles falls to 80% of the as it was at initial condition.To offer adequate operating time to the device supposed to power, 80% is the minimum capacity that is needed. Though it could be operate more than specified cycle life. The battery degrades rapidly after the 80% point and with each additional cycle more capacity is lost.

3.4. Buck Converter dc/dc:

The under topic converter has been assigned for altering coming dc input to a workable dc output. It is used along with voltage and current control in this work. A PID control strategy is implemented with buck convertor which gives assistance. A closed loop mechanism is developed in the proposed system.

The MATLAB/Simulink is selected to be utilized for the required circuit design. The buck is used for the voltage level step down.

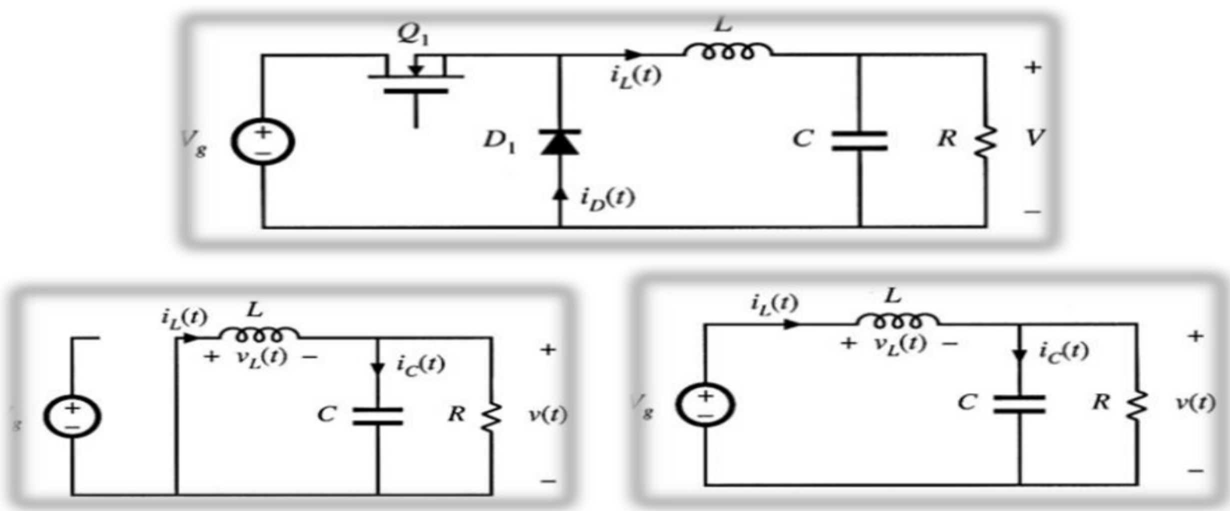

Figure 3. 2 (a) Buck Convertor, (b) Position 1 (C) Position 2

Position 1:

The figure 3.2(b) shows position P1, when the key is open and conduction by diode is illustrated, by applying KVL ,

$$v_L = -V \tag{3.9}$$

Position 2:

The figure 3.2(c) shows the P2 of closed switch and the current passes through inductor, the equation which arises by applying Kirchhoff's voltage law at p2;

$$v_L = v_g - v \tag{3.10}$$

3.4.1. Volt Second Balance:

In balance state inductor's overall voltage equals 0. Applying defined condition we have;

$$v_{L1} + v_{L2} = 0 \tag{3.11}$$

By putting values and having solution we have;

$$v = Dv_g \tag{3.12}$$

Ripples in Inductor Current

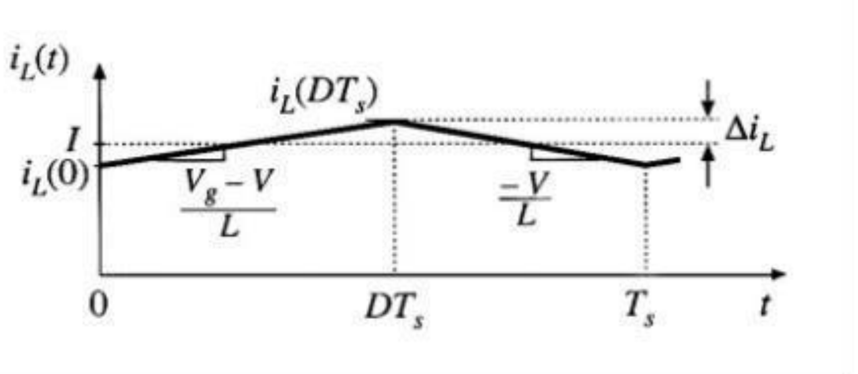

Figure 3. 3 Inductor Current Ripple

The value of inductor found through mathematics:

$$\mathbf{L} = \frac{V_g - V}{2\Delta_{iL}} D\mathbf{T_s} \tag{3.13}$$

3.5. Proportional Integral and Derivatives (PID) Control:

It is a common technique extensively implemented for various processes in industries. It is easy and simple for implementation.

Proportional, Integral and Derivative are the three parameters of this system. The term proportional deals the difference that has occurred, the second part governs errors' accumulation that has occurred and the speed of altering is determined by derivative part. These three actions can be used together to control a procedure through a component which could be a control valve or something else. Any action for any definite process can be controlled by having them together. The intensity of error decides the behavior and response of controller.

3.6. Buck control strategy:

The unregulated input voltage into controlled DC output voltage is being converted through buck as mentioned earlier. This electronic device with progressive digital control have several useful features. Thee promising conditions combine opposition for environmental developments, extended flexibility by altering the software, more advanced control approaches, incorporation electricity controlling features , moreover reduced amount of constituents. This method of controlling is simple, easy and robust. For refining processes PID-controller technique is better and robust.

3.7. Dynamic Charging Method:

Electric Vehicles parking lots can be converted into charging station by installing solar panels to provide green and clean renewable energy for charging. Apart from electricity production for charging it provides shade for EVs as well. The PVs uses solar energy directly to produce electrical energy. But the output power of PVs is intermittent because the solar insolation does not remain same throughout the day. It will give maximum output power in a sunny day, but the power will be reduced in a cloudy day. The dynamic charging technique is the charging method for batteries charging which will charge the batteries on priority bases using the available output power. The priority on which the charging take place must be defined. In this work the batteries of electric vehicles will be charged according to SOC of battery and the parking duration of EVs in parking lot.

3.8. Fuzzy Control:

The FLC is range to range control that takes value between 0 and 1. In classical control the truth value only deals with zero and one, but this logic also takes the value 0 and 1 both inclusive and the point in between them. Using the related membership functions the process gives the value which we are trying to get. This control works on the same base as human brain. It does not gives a constant value but select a range of values.

3.8.1. Membership Function:

Membership function denotes the fuzzy subsets of X. For every input variable and output variable different membership functions are selected according to the condition. If a triangular membership functions are selected it will be given three values in the similar way rectangular and trapezoid takes four values. Gaussian type membership function could also be selected.

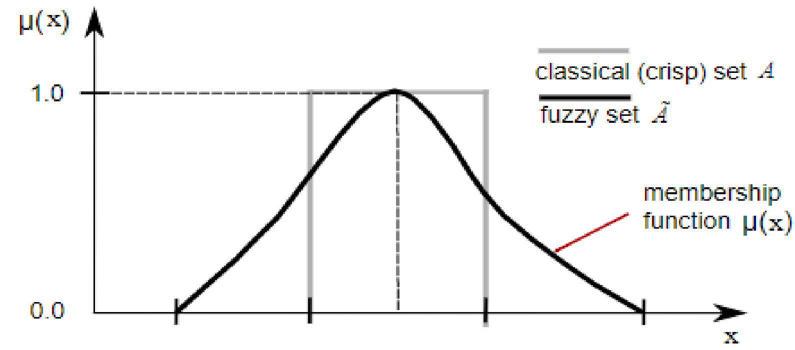

Figure 3. 4 Membership function of fuzzy set

3.8.2. FUZZIFICATION:

Fuzzification is the process to transform definite given values or the number values to the values which could be the possible solution using the information in knowledge base. The values given to the system is exact whole values which do not have range, but the values after the process comes to be in range of values not exact one value.

3.8.3. The Inference System:

It combines different function of the system with designed laws to originate systematic product . This aforementioned process is an important unit of a FLS, which makes decision. Employing "IF…THEN" rules beside connectors "OR" or "AND" for making vital decision rules. The input can be fuzzy or crisp, but the output from FIS is always a fuzzy set.

3.8.4. Defuzzification:

This process in integration with the two processes discussed above creates computable outcome in crisp logic. It changes fuzzy set to crisp set. A number of variables with a number of rules are transform into fuzzy set, in fuzzy sets products or outcomes is always in the form of system.

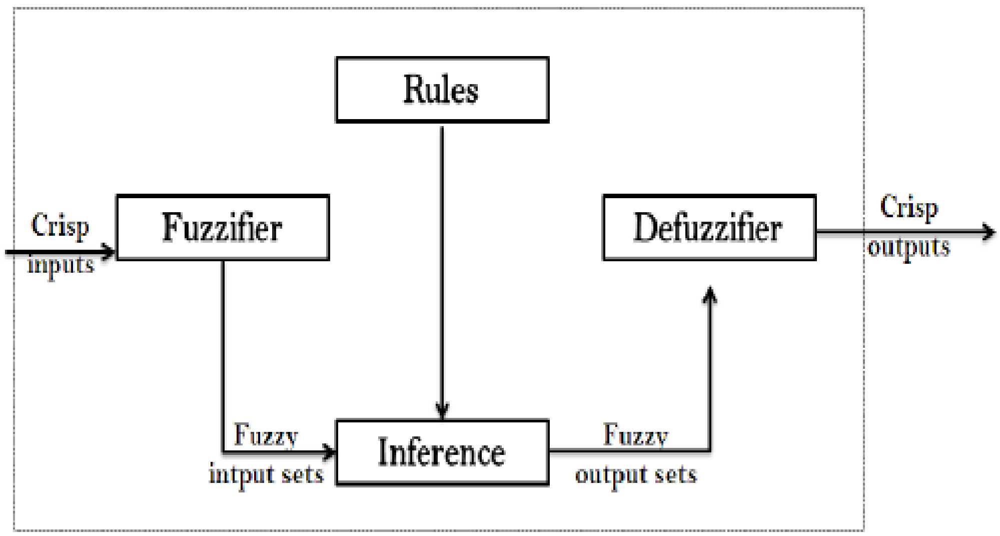

Figure 3. 5 Fuzzy system working

3.9. Designed Fuzzy Model:

The proposed model is designed by defining two input variables for the fuzzy which are SOC of the battery and duration of stay for each EV in the charging station. Outcome variable of the system has been taken to be Reference Current. Three MF of triangle style are taken for all the found are to be found variables.

3.9.1. Input Membership Function:

Three triangular MF with three assigned values are described for the two given variables. Low, medium & high for SOC of the battery and short, moderate and long for duration. The range for SOC is 0 to 100 while range of duration is 0 to 12. Three parameters are selected for both the assigned given quantities. Below picture 3.6 shows the designed MF of input variables with all the necessary information which needs to be mentioned.

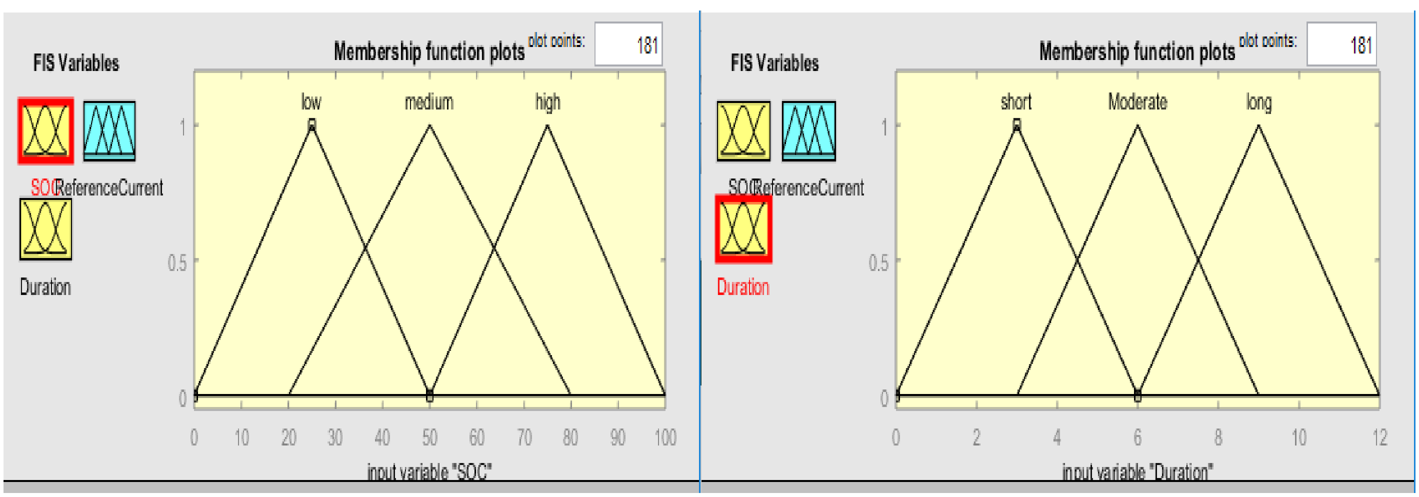

Figure 3. 6 Input variables membership functions

3.9.2. Output Membership Function:

For output variable three triangular membership function are defined which are low current, medium current and high current. Figure 3.7 shows the outcome MFs.

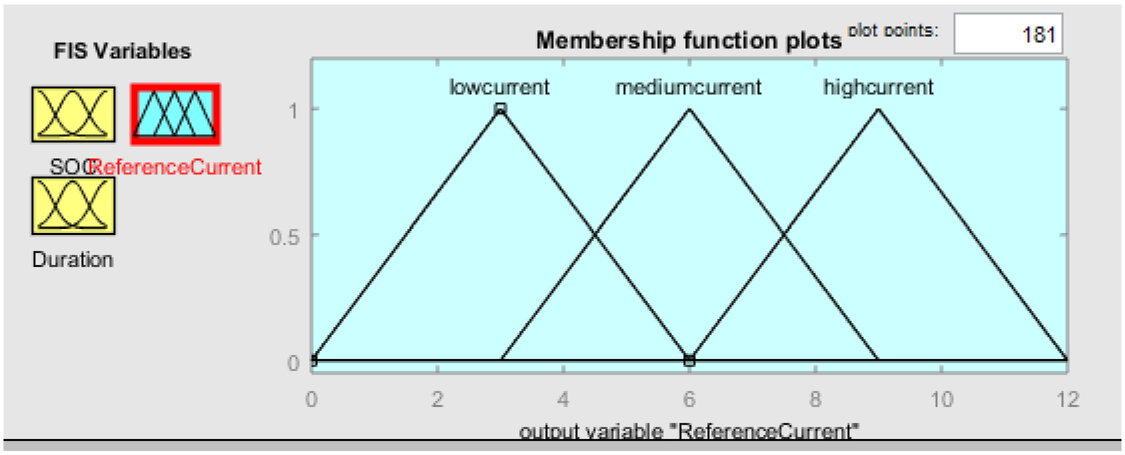

Figure 3. 7 Output Membership Functions

3.10. Rules for Fuzzy System:

Below picture 3.8 shows nine rules developed in fuzzy using MATLAB or simulink.

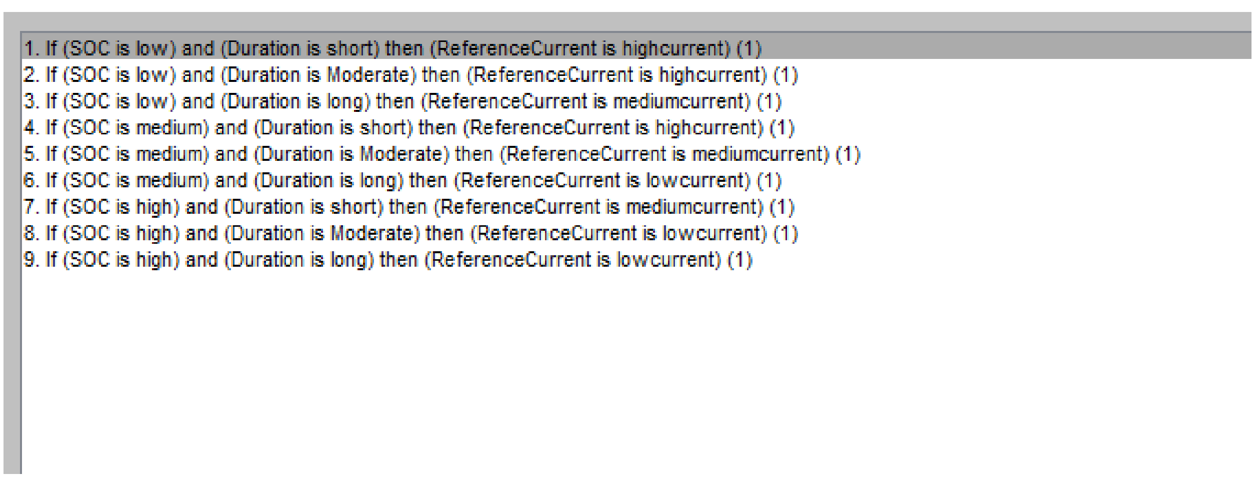
1. If (SOC is low) and (Duration is short) then (ReferenceCurrent is highcurrent) (1)
2. If (SOC is low) and (Duration is Moderate) then (ReferenceCurrent is highcurrent) (1)
3. If (SOC is low) and (Duration is long) then (ReferenceCurrent is mediumcurrent) (1)
4. If (SOC is medium) and (Duration is short) then (ReferenceCurrent is highcurrent) (1)
5. If (SOC is medium) and (Duration is Moderate) then (ReferenceCurrent is mediumcurrent) (1)
6. If (SOC is medium) and (Duration is long) then (ReferenceCurrent is lowcurrent) (1)
7. If (SOC is high) and (Duration is short) then (ReferenceCurrent is mediumcurrent) (1)
8. If (SOC is high) and (Duration is Moderate) then (ReferenceCurrent is lowcurrent) (1)
9. If (SOC is high) and (Duration is long) then (ReferenceCurrent is lowcurrent) (1)

Figure 3. 8 Rules for Fuzzy Logic Control System

Chapter 4

Simulation and Results

CHAPTER 4. SIMULATION AND RESULTTS

4.1. SIMULATION:

MATLAB/Simulink proved to be useful for the design of this model. The figure 4.1 shows simulated design of the charging point in which ten Electric Vehicles are shown which are getting charged by a DC source. The DC source is taken as Photovoltaic which gives DC power for Electric vehicles. The cars are connected in parallel combination.

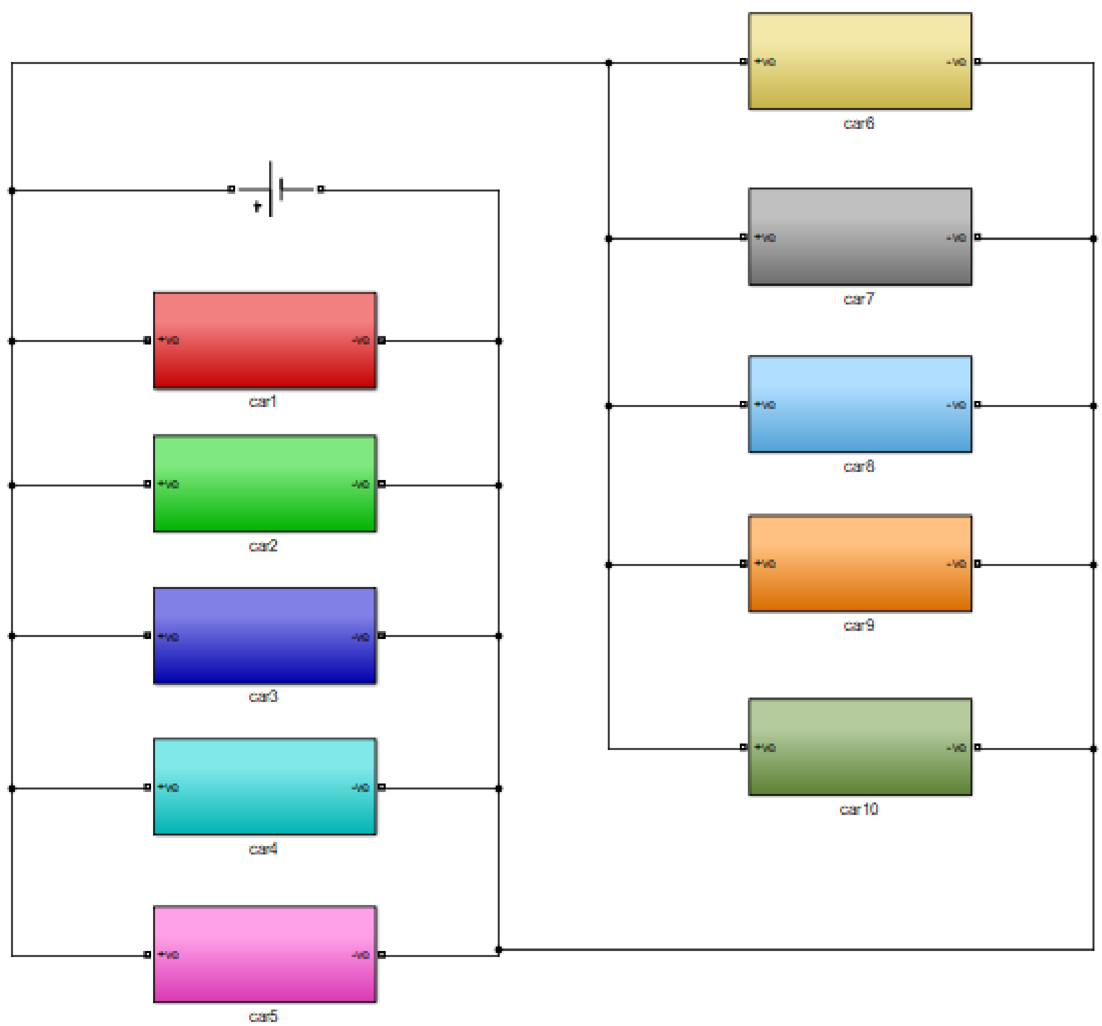

Figure4. 1 Simulated Model with control for EVs charging

4.1.1. Simulated Charging Model:

The figure 4.2 shows the simulated charging model for EVs charging with Fuzzy Logic controller (FLC) simulated in MATLAB /Simulink.

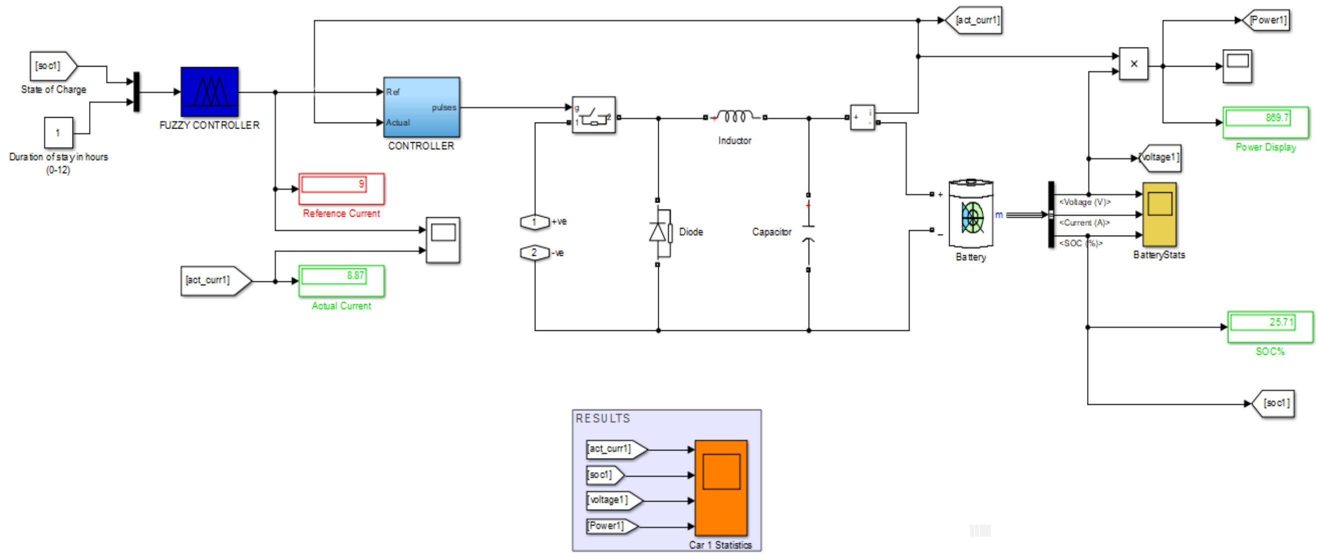

Figure4. 2 Simulated charger for EVs with control in MATLAB/Simulink

4.2. Results:

The simulation was run for 60 seconds and the results for each EV are given as under. The parameters like current, voltage , power and SOC of the battery are investigated. The controller is working for both the input variables, the SOC of the battery and duration of stay at charging station. If an EVs battery has low SOC and less duration of stay the controller will give high current to that specific car than the other and vice versa. The results show the controller is working for both the inputs. Results for each car is given and discussed.

4.2.1. EV-1:

The EV-1 has initial SOC of 25.9% and the stay time at station is 1 hour. The system has given 8.7889A current to charge the battery. The SOC has increased to 40.03 percent. The voltage is 140V during the charging. The figure 4.3 shows the results for EV-1.

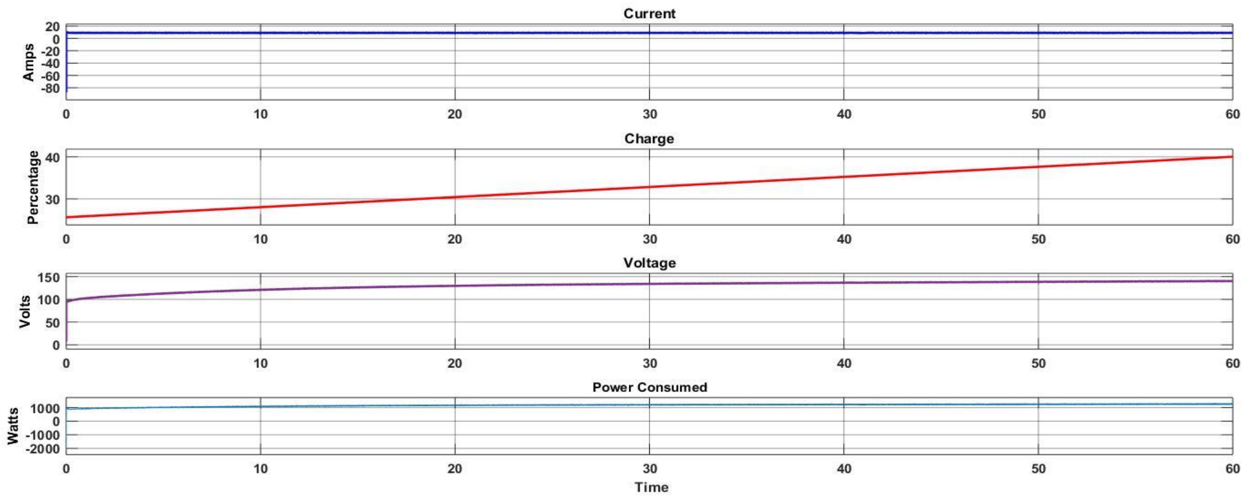

Figure4. 3 Simulation results for EV-1

4.2.2 EV-2:

The EV-2 has initially battery SOC of 53.7%. The reference current is 7.404 A and the actual current is 7.3 A. The battery is charged to 64.993% of SOC. Figure 4.4 shows results for EV-2.

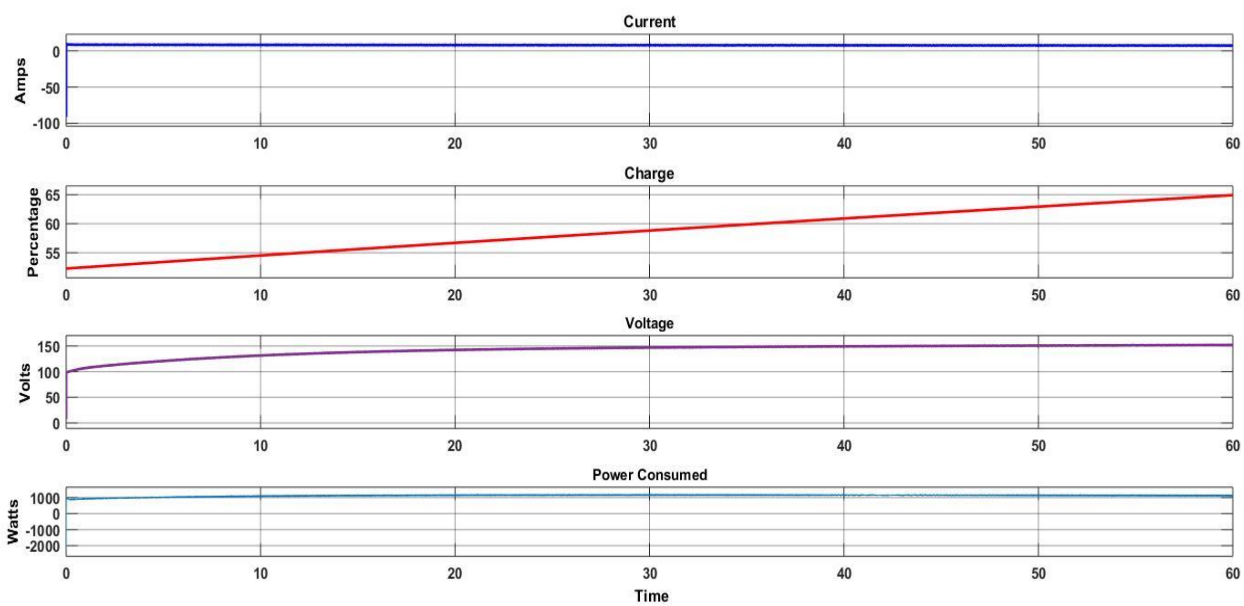

Figure4. 4 Simulation results for EV-2

4.2.3. EV-3:

The EV-3 stays in the charging station for 3hrs. the SOC increases from 77.8 to 87.4% with 5.763A current. Figure 4.5 shows simulation results for EV-3

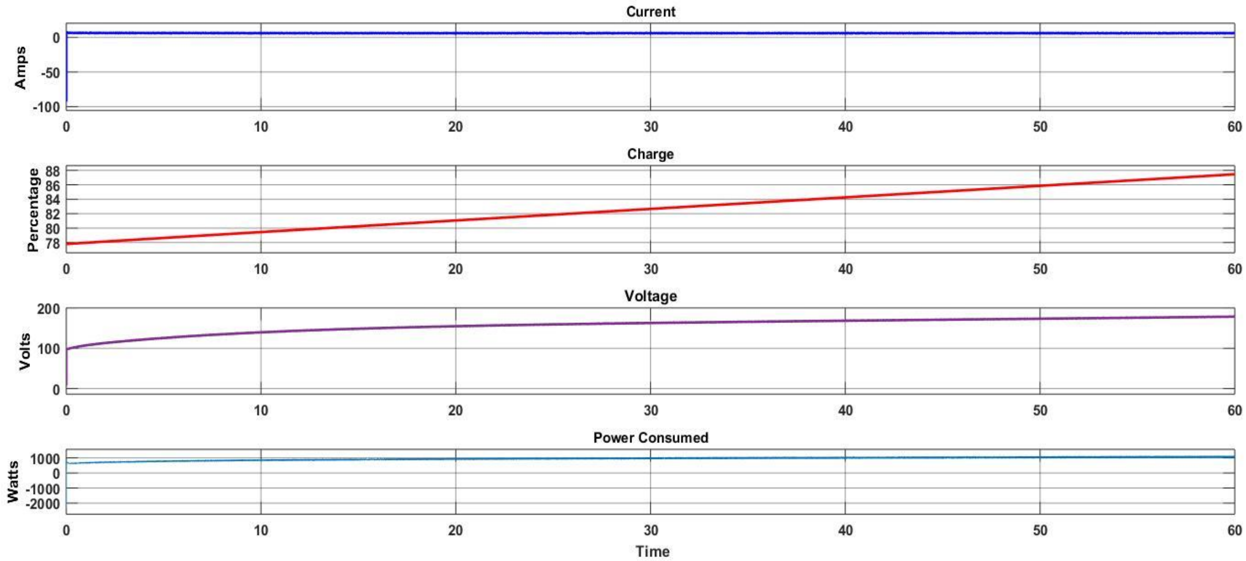

Figure4. 5 Simulation results for EV-3

4.2.4 EV-4:

EV-4 has 89% SOC initially it has increased to 96.16%. the duration of time assigned is 4 hrs. the actual current is 4.683A and reference current is 4.5A.Figure 4.6 shows results for EV-4.

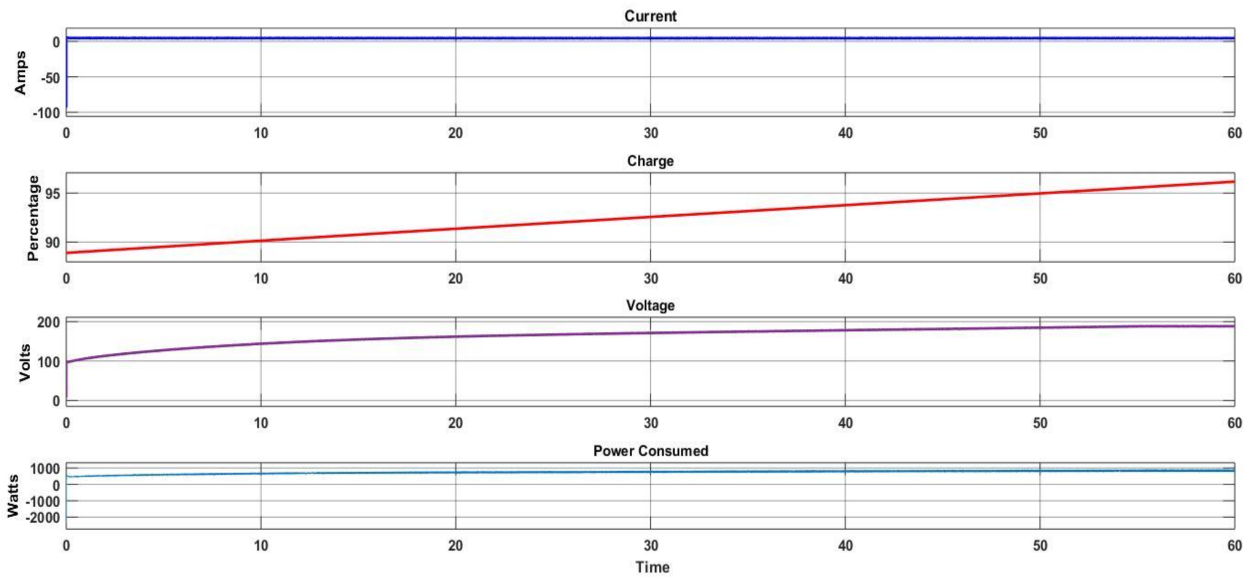

Figure4. 6 Simulation results for EV-4

4.2.5 EV-5:

EV-5 has 5.3% charge, its duration of stay is long 9hrs. The charging current is 3.326A Figure 4.7 showing result for EV-5.

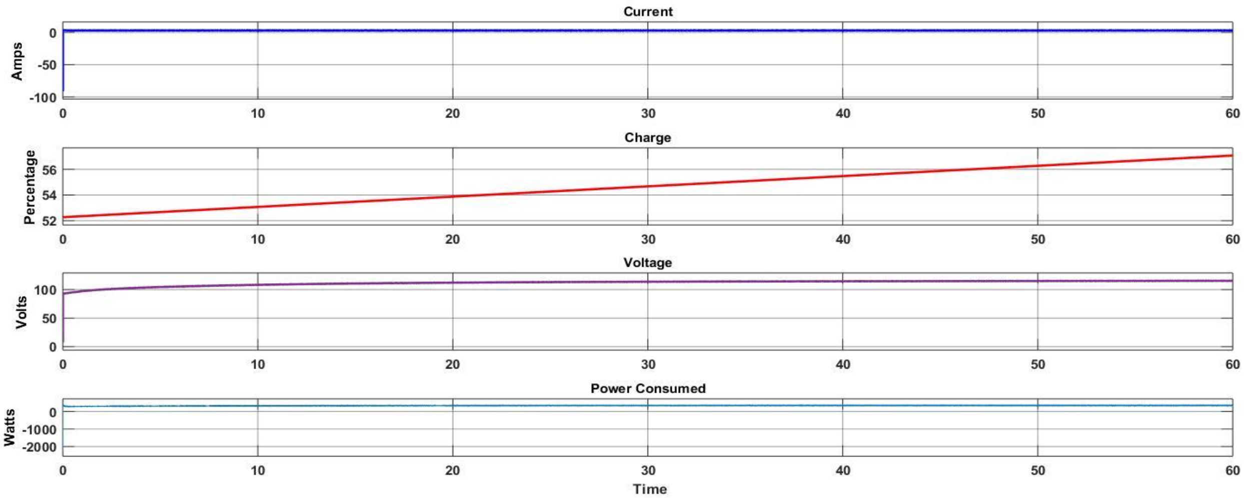

Figure4. 7 Simulation results for EV-5

4.2.6. EV-6:

The EV-6 has 16.7553% SOC initially and 11hours duration of stay. The battery SOC has increased to 16.87% because it has long duration off stay. Figure 4.8 shows EV-6 simulation results.

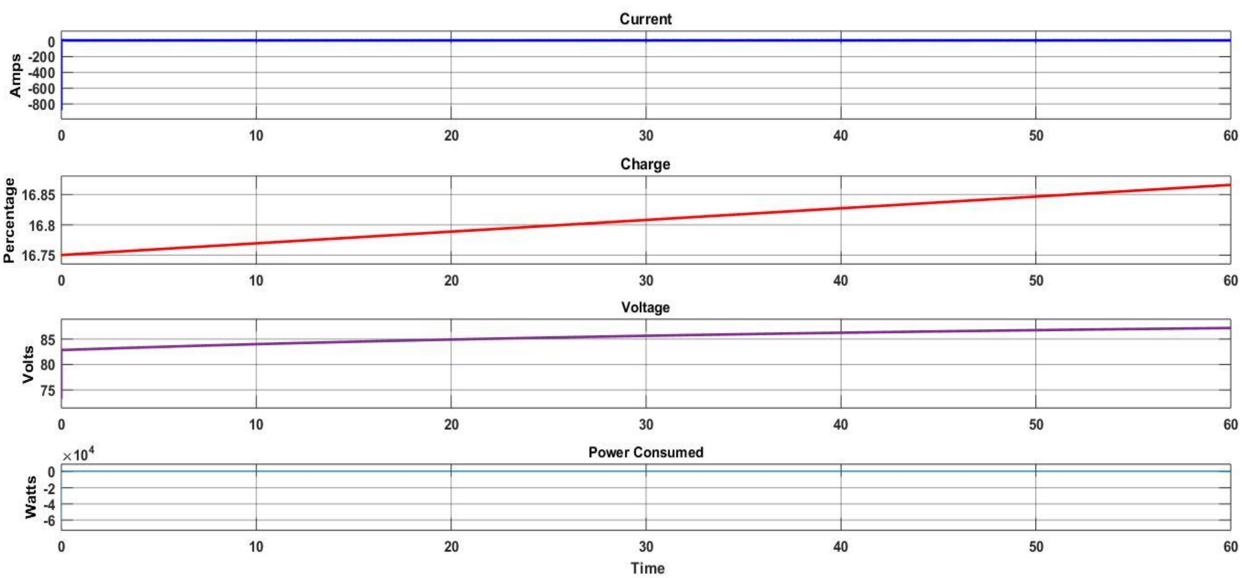

Figure 4. 8 Simulation results for EV-6

4.2.7. EV-7:

Figure 4.9 shows results for EV-7 in which the battery SOC has increased from 44.52 to 44.52%. The current is 5.429A. The voltage is 96V.

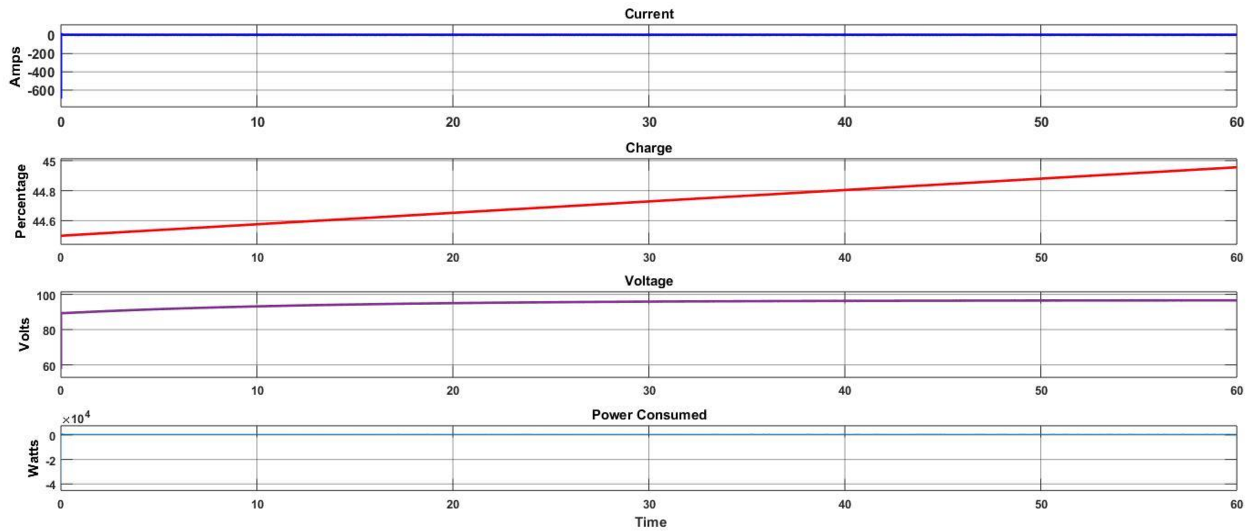

Figure4. 9 Simulation results for EV-7

4.2.8. EV-8:

The EV's battery has charged from 72.26 to 72.56%. Current is 4.105A and duration of stay is 8hrs. Figure 4.10 showing result for EV-8.

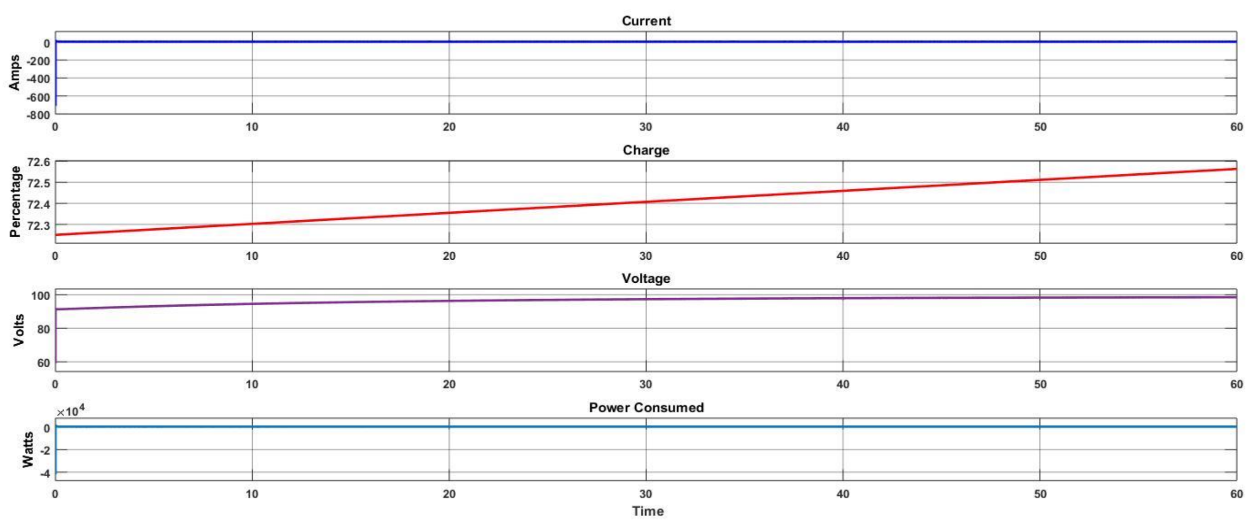

Figure4. 10 Simulation results for EV-8

4.2.9. EV-9:

The figure 4.11 shows the increase in EVs battery SOC slightly. Duration of stay is 9 hours.

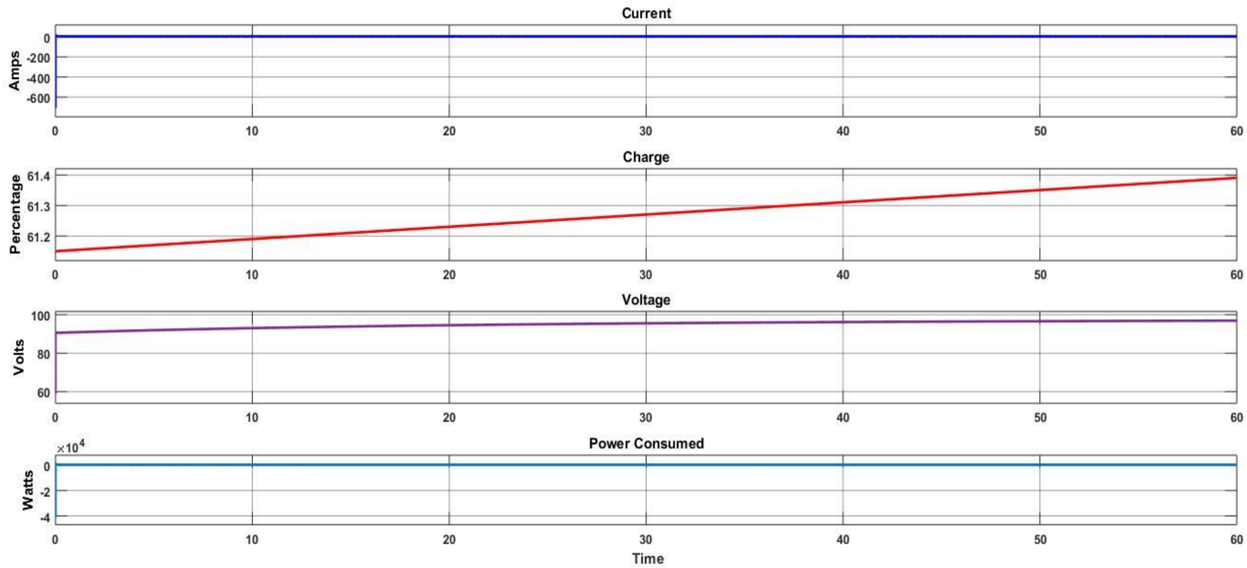

Figure4. 11 Simulation results for EV-9

4.2.10. EV-10:

The EV-10 has 10 hours duration of stay. Power consumed is 422.5W, current is 4.471A and initial SOC is 33.4% . The figure 4.12 shows results for EV-10.

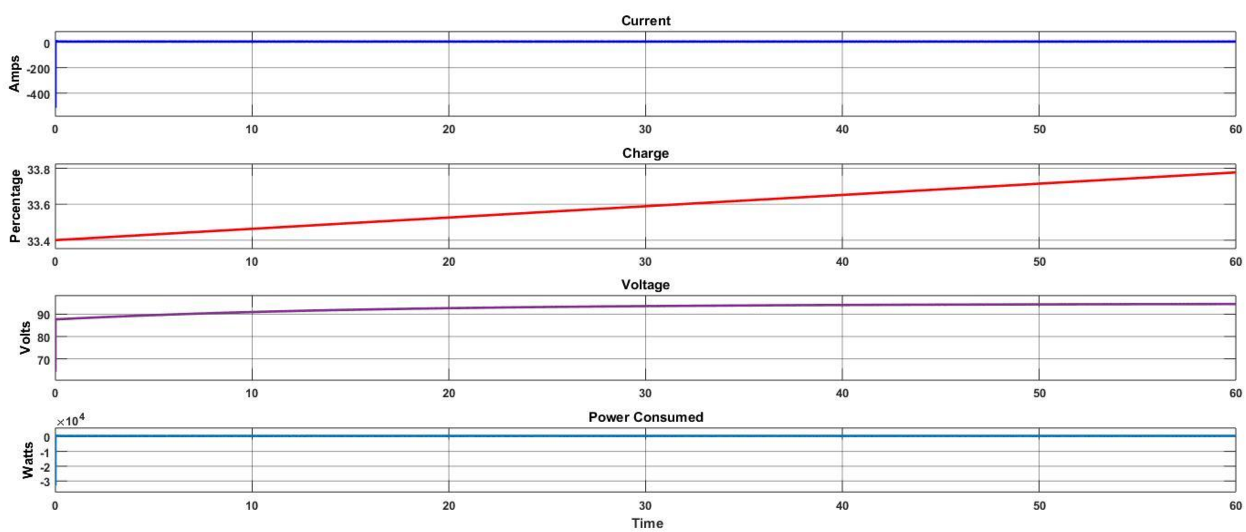

Figure4. 12 Simulation results for EV-10

Chapter 5
Conclusion and Future Work

CHAPTER 5. Conclusion And Future Work

5.1. CONCLUSION:

The proposed charging station model with Fuzzy Logic Control is developed, controlled and totally worked on in MATLAB (Simulink) environment. A charging technique based on fuzzy logic is suggested to manage the electric cars recharging in place where they parked in reasonable and prime manner. To accomplish this undertaken task in a well and unique manner the FIS is is developed and checked to assign charging priorities for all coupled parked cars based on the available power, available charge in the battery of the vehicle and the time for which the owner wish to park it. For EVs the priorities are set by assigning rules in fuzzy according to state of charge and the time duration for which the EV will be parked in the parking station for charging. The model is designed for ten EVs that could be charged from ten slots at a time. The results of the work validate that the proposed design is capable of meeting the EV charging demands in a quite effective way for different situations.

5.2 Future Work:

The proposed work has ten EVs charged on priority bases in respective charging slots, but in the future more slots can be designed for more cars charging on priority. Beside this Adaptive Neural fuzzy Inference system can be used instead of fuzzy logic system which could be more robust control technique. This work can be extended and used for commercial purposes. Different control technique can be used by integrating with the grid for extension of the work.

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