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Design, Specification and Simulation of Slow & Fast Battery Charging for Electric Vehicle Application

Santosh Kumar G
M.Tech, Power Electronics Engineering, Rashtreeya Vidyalaya College of Engineering, Bangalore, India.

Hemalatha J.N
Assistant Professor, Dept. of Electrical and Electronics Engg., Rashtreeya Vidyalaya College of Engineering, Bengaluru, India.

Abstract – In global scenario sustainability is major concern, in order to reduce the dependency on fossil fuels there is shift towards electric vehicle this made sale of electric vehicles (EVs) increase rapidly around the world and EVs' efficiency and extended battery life and quality is lowering EV's cost of purchase. Charging configurations play a vital role in an electric powered automobile. Charging systems can be categorized into three levels i.e. level 1, level 2 & level 3. This paper presents the topology that will interphase the two types of charging systems i.e. to charge the battery in both slow and fast charging. TESLA S60 battery model is taken as an example for specification and both modes of charging will have CUK converter to drive the charge for battery. The MATLAB/Simulink software is used to simulate the battery charging model that in turn charge the lithium-ion battery model.

Index Terms – CUK converter, Electric vehicle, MATLAB/Simulink

1. INTRODUCTION

Modern society relies heavily on fossil fuel-based transportation for economic and social development, freely moving goods and people, a combustion engine only uses 30% of the fuel and rest of all is loss while in case of electric motor efficiency is more than 80% . Since the electric vehicle (EV) is propelled with the help of an electric powered motor, powered by means of rechargeable battery packs, in preference to a gasoline engine [1]. Battery electric powered cars comprise vehicles, buses, forklifts, bicycle, rail cars, and scooters. The beneficial instances in battery storage generation have moreover undoubtedly influenced the electric car battery marketplace [2] .The sale of electrical automobiles (EVs) is swiftly increasing around the world because of EVs' efficiency and increased battery technology that is reducing EV's cost of buying. Electrical vehicles depend on electric batteries to present the essential or the auxiliary power. Along these flow any effect on the demand for electric vehicles can influence the electrical vehicle battery market. An electric powered automobile makes use of mixture energy positioned away in rechargeable battery packs for manage. As all of the capacity is taken from batteries therefore, it does not need any combustion engine for doing it more quickly. The lead acid & lithium-ion batteries are used mostly. The lithium-ion battery have several advantages over lead acid battery like reduced size for same battery capacity the charging of batteries is the only area were modification is possible to have more efficiency and also charge per distance will also going to be increased. Charging modes can be categorized into 3 degrees in keeping with Society of Automotive Engineers (SAE). On-board charging & off board charging are the two ways of charging schemes for EV's. In on-board charger the charging circuitry will be situated in the electric vehicle and charging coupler is used give input power but in Off-board charger the charging circuitry will be outside the vehicle normally charging for electric vehicles are done in two ways one is from home outlet and another is through charging station. In home outlet charging only level 1 charging is achieved but in charging station all charging modes will get i.e. slow, fast & 3-phase charging. In this project, the on-board charger is accomplished. The 3 degrees of charging are Level 1 charging (1-phase slow charging), Level 2 charging (1-Phase & 3-phase slow and fast charging), and Level 3 charging (3-phase fast charging) [3].

Table1.1: charging levels

Charging options	Current rating (amp)	Voltage Rating (volt)	Power Rating (kW)
Level 1 charging (1-phase slow charging)	12 to 16	120	1.3-1.9
Level 2 charging 1-Phase & 3-phase slow and fast charging	Upto 80	240	Upto 19.2
Level 3 charging (DC fast charging)	Upto 80	480	Upto 130

The objective of this paper is to design a system that interphase the On-Board AC slow charging and DC fast charging and simulate the converter in MATLAB/Simulink software for different values of charging time. Organization of paper is section I the introduction to electric vehicle, battery scenario & charging schemes in section II block diagram of the proposed charging scheme in section III design of converter in section IV simulation of converter and the results in section V conclusion.

2. BLOCK DIAGRAM OF THE CHARGING SYSTEM

The block diagram Fig 2.1 consists of different block that defines two charging schemes. The slow & fast on-board battery charger includes double circuit for slow as well as fast charging. In slow charging includes double conversion like AC to DC and DC to DC. Initially AC-DC conversion occurs using rectifier to have makeover of voltage for output and DC-DC provides constant output to the battery using CUK converter topology. The gating pulses are provided to DC-DC converters to maintain constant output current by taking feedback. This feedback signal is given to Aurdino UNO to generate appropriate gating signal required.

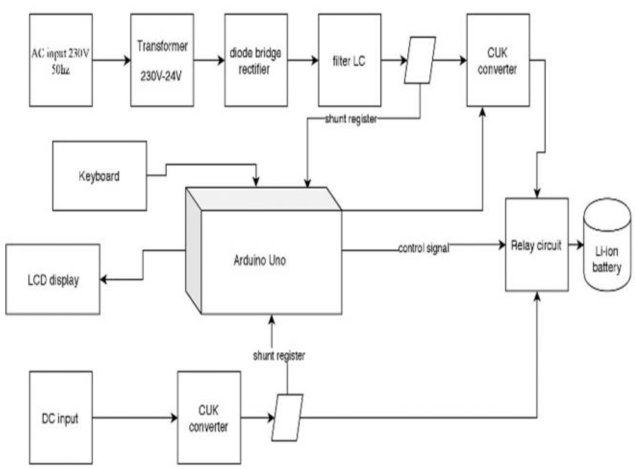

Fig: 2.1 Block diagram of the charging system

To take desire values for simulation an example of electric has been taken i.e. TESLA S 60 Model and the ratings are given in Table2.1

Table2.1: Example of TESLA S60 model

EV in market	Battery rating	Range km	Wh/km
Tesla S 60	60kWh	275km	220 (335mi)

Calculation of load power:

P=890A*320V =285 Kwh (1)

Battery capacity selection

= 890A * T = 890 * 0.21 (2)

= 190Ah

Charging time of the battery:

$$T=\frac{battery\ power\ rating}{load\ power}=\frac{60*10^3}{285*10^3} \quad (3)$$

T=34 min

3. DESIGN OF CONVERTER

Normally the CUK converter is chosen to reduce down the voltage approximate for battery nominal voltage the respective specifications and circuit are:-

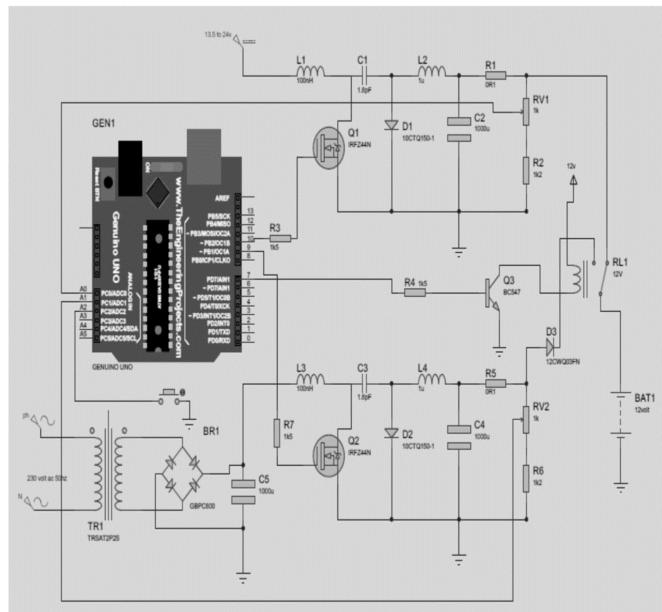

Fig: 3.1 circuit diagram of the converter

In Fig 3.1 the main circuit diagram is shown which have CUK converter with close loop from Aurdino UNO it has the two inputs and a single battery that is going to charge. The output voltage and inductors values are designed.

$$V_o=-V_s\frac{D}{1-D} = -400\frac{0.2}{1-0.2} = -72V \quad (4)$$

$$L_1=\frac{V_S D}{f\Delta_{iL1}} = \frac{230*0.35}{50000*1/100} = 100nH = L_3 \quad (5)$$

$$L_2=\frac{V_S D}{f\Delta_{iL2}} = 1uH = L_4 \quad (6)$$

$$C_1=\frac{V_S D}{Rf\Delta_{iL1}} = \frac{400*0.35}{0.9*50000*2/100} = 1.8pF \quad (7)$$

$$C_2=\frac{1-D}{\left(\frac{\Delta V_o}{V_o}\right)8L_2 f^2} = 1000uF \quad (8)$$

The inductor and capacitor values are evaluated as considering respective formula from design

Table3.1: specification of the converter

Sl No	Values	Rating
1	Input voltage (AC) charging	230V
2	Input voltage (DC) charging	400V
3	Output current (AC)	20A
4	Output current (DC)	190A

4. SIMULATION OF CONVERTER

Simulation is done in the MATLAB/Simulink software and results are shown:-

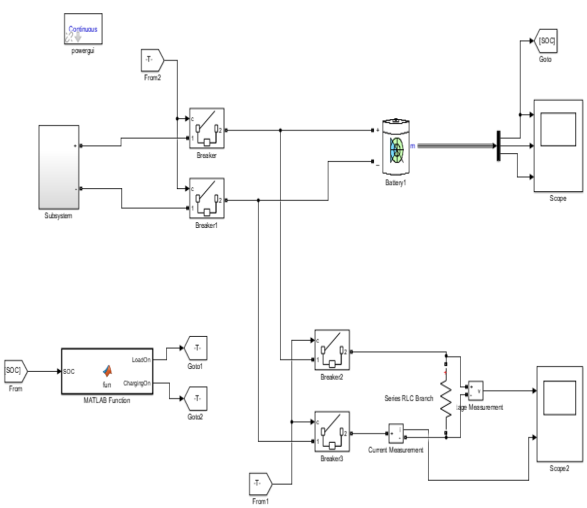

Fig: 4.1 Simulation of converter in MATLAB/Simulink

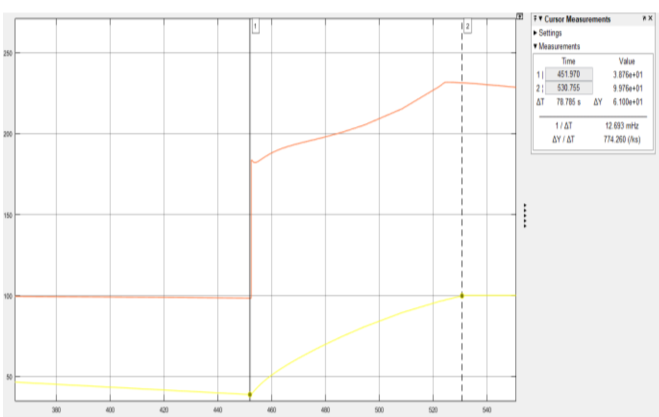

Fig: 4.2 simulation results

In the Fig 4.1 the MATLAB circuit is given in which the converter is simulated to get desired battery characteristics i.e. charging and discharging plots. In Fig 4.2 the waveforms is with respect to the fast charging of battery that takes 190A and charges in 1 hour. In Fig 4.3 the waveforms is with respect to the slow charging of battery that takes 20A and charges in 5.5 hour.

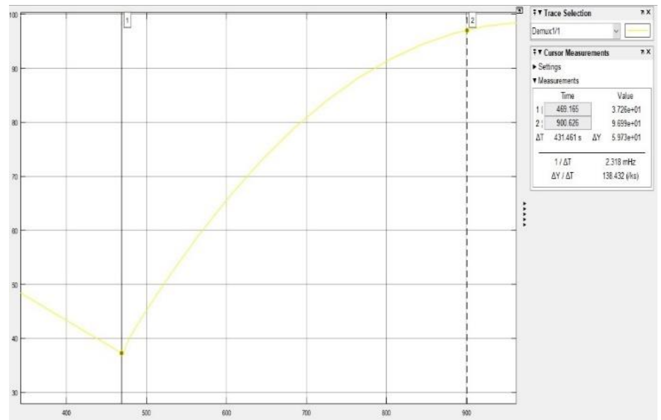

Fig: 4.3 simulation results

Table4.1: simulation results

Battery 190Ah	
Charging Current	Time for charging
20A	5.5 hours
190A	1 hour

5. CONCLUSION

In this paper the two types of charging systems which are interphased to charge the battery in both slow and fast charging are been analysed, designed and simulated in MATLAB/Simulink software and from results it is clear that a proposed circuitry can be used for fast as well as slow battery charging. As per results slow charging is around 5.5hours through 20A current and fast charging has 1hour through 190A of current.

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Authors

Santosh Kumar G '24 from Raichur, Karnataka and pursuing post-graduation in R.V. College of Engineering, Bengaluru and graduated from Navodaya Institute of Technology, Raichur with Distinction. Paper Presentation in "National Conference on Knowledge Dissemination of PG Projects and Research Works" Workshops attended "INSULATED POWER CABLES AND INSULATION" by Dr. HARRY ORTON, "Improving Power Quality Using FACTS Devices in Electrical Power Systems" by Dr. NAGESH PRABHU, INTERNSHIP Program at ABB India Pvt Ltd. Peenya, Summer Trainee "Raichur Thermal Power station.

Prof. Healatha J N , Assistant Professor R V College of Engineering Bengaluru. Ph.D. pursing and Post graduated from University Visvesvaraya College of Engineering Bengaluru. Has 16 Years of teaching experience and author of more than 15 papers in National and international Journals