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Automated Fast Charging Infrastructure Using in Transport System of Electric Vehicles

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***Abstract*—The main objective of this paper represents electric vehicle battery charging to meet the daily trip schedule with minimum number of vehicles. The fast-charging infrastructure of battery includes automated charging and power conversion. The power conversion stage is designed with uncontrolled full bridge rectifier and boost converter in DC/DC conversion stage to set nominal voltage for charging of battery. The charging process is automated for measuring the state-of-charge (SOC), identifying the arrival of car events at charging stations and charging circuit control through FPGA board. The proposed charging of battery is validated by simulation results using MATLAB/Simulink environment. The simulation results confirm the effectiveness of the proposed system design, ensuring that the energy demand of the EVs is successfully covered the charging station batteries operate out of the low charge zone.**

Keywords*—Electric Vehicle, Charging circuit, Control circuit, Sate-of-charge (SOC), PID controller, 3phase full bridge rectifier, Boost convertor, FPGA.

I. INTRODUCTION

Nowadays, electric vehicles charging structure play important role because of the reliability and energy security of electric vehicles. The main factor leading to high carbon dioxide emission is from the internal combustion engine vehicles (ICEVs). Electric vehicles (EVs) present a huge potential in becoming an attractive alternative to ICEVs because of their environmental advantages and globally increasing day to day oil prices. Therefore, electric vehicles (EVs), which can achieve zero pollution-emission operation. The charging infrastructure is composed of an operating system, charging and customer operating system. Among these, the charging system is most integral component of the charging infrastructure. The charging structure needs to be compatible with the EV battery system and are classified as a fast or slow charger depending on the power it handles. The fast charger usually handles 50 Kw of power and takes less than an hour. The slow charger handles 3-4 Kw of power and takes approximately 6-7 hours for full battery charging. For this reason, the slow charger is utilized for charging using a household grid power during the night time. Most of the electric vehicle manufactures in view of optimum battery size for a given range are going for the battery that can take high charge current and thus necessitate fast charging facility.

The fast charger can be installed in [2] public places or at petrol pumps. Driving longer distance and lesser refueling time are the prime concerns of EV users which need to be addressed to make the electric vehicle popular among the masses. Fast charging addresses the concern of charging the vehicle battery and is considered as one of the technological advancements in EV domain.

Recently, the continual production of the Lithium-ion batteries and EVs along with the notable price drop have advanced the role of the electric vehicles in power grids. Consequently, the growth of EV connection to the power grids is inevitable. V2G connection can be categorized into unidirectional and bidirectional. The unidirectional connection only enables EV to change the charging rate for their batteries based on the power grid status. This action can prevent grid overloading, system instability and voltage issues [1]-[2]. However, the bidirectional EV connection provides grid and EV to interact in both ways. In the other word, the bidirectional V2G provides more flexibility and possibility to exchange power between the EV and power grid. EVs can inject or consume active power depending upon the daytime and necessities. The battery in EV can be considered as load when the EV charges from power grid or it can be backup energy storage when the electric vehicle discharges into the power grid. Active power support from bidirectional V2G can achieve peak load shaving and load levelling services. These services achieved by charging the EV during the off-peak hours and inject additional EV energy into power grid during on peak hours.

In [6] our paper we model charging system of fast vehicle battery in MATLAB / Simulink. The charging system of electric vehicles can be divided into three levels. The charging structure can be including bridge rectifier boost circuit, converter and constant voltage control is used for the converter. In the grid connected mode, the system needs battery storage system to generate the lack of loads demands. And also studies different charging technologies of electric vehicles.

Typically, rechargeable batteries are electricity storage system to store electrical energy. The minimal battery usage will SOC is at its minimum value. In the case of grid - connected system, the power is drawn from the grid to charge the batteries when their SOC is decreasing to its minimum level. Therefore, the batteries must be charged by the utility grid and subsequently optimize the batteries utilization.

II. EVs CHARGING TECHNOLOGIES

A. Different Charging Technologies:

Automotive industry standards classify charging stations into three levels based on charging power and methods: AC Level 1, AC Level 2, and DC Fast Charge.

1) AC Level 1 is the slowest form of charging that uses a standard household outlet (120V). It provides a range of up to 5 miles per hour and is, therefore, not suitable for those who travel more than 40 miles per day.
2) AC Level 2 charging uses service equipment to provide power at up to 240V. It provides 10-25 miles of range in an hour of charging at home or public station.
3) DC Fast Charge is currently the fastest type of charging providing up to 40 miles of range for every 10 minutes of charging.

B. Electric Vehicle Charging Station:

Electric batteries are one of the common sources of energy to battery electric vehicles and PHEVs. The availability of fast charging stations to energize the batteries on a long journey is one of the challenging factors in [3] the adoption of the EVs. Charging of batteries relies upon the kind of EV, type of battery, leftover charge in the batteries, and the type of EVs. Figure 1 shows the different charging technologies used for EVs.

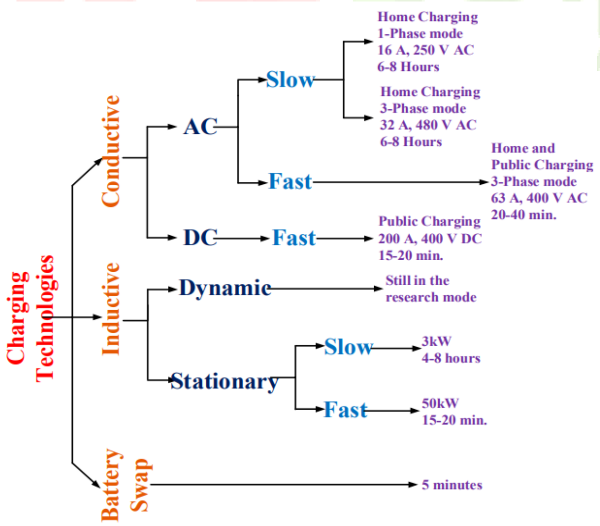


Fig. 1: Different charging technologies

III. CHARGING INFRASTRUCTURE

This charging infrastructure consists of two input stages are 1]. Rectifier: A rectifier is a diode which converts AC grid supply to DC, for our work we have chosen 3phase full bridge rectifier.

2]. Convertor: Convertor which converts into DC voltage in order to step up or step-down voltage.

The main work [4] of thesis is to identify the different components of power electronics which can fulfill the power requirements of each charging stations. The charging system includes three levels are diode rectifier, boost converter and constant voltage control.

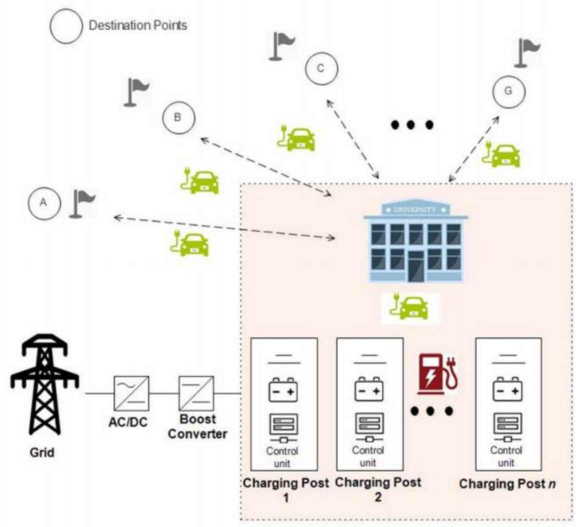


Fig. 2: Conceptual design of proposed system with fast charging infrastructure

A. *. Diode Rectifier:*

A rectifier transforms alternating current into direct current. Its normal function is charging batteries and keeping them in optimum conditions, while considering the power storage strategy from the grid overnight. Post recharges of electric vehicles battery can reduce the electricity costs and power supplies to EVs batteries through the day time. In our work we can be used to the electric vehicles batteries and this can be performed with the 3phase full bridge rectifier in MATLAB / SIMULINK.

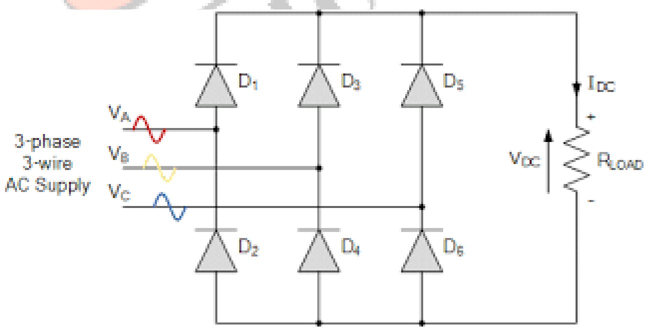


Fig. 3: 3-Phase full bridge rectifier

B. *Boost Convertoer:*

This converter appears in Fig. 4 Using IGBT diode or MOSFET or simple diode with initial parameter values in MATLAB / Simulink. The boost converter is used to "step-up" an input voltage to some higher level, required by a load. This unique capability is achieved by storing energy in an inductor and releasing it to the load at a higher voltage. Boost converter is used to get set voltage from the given reference voltage. Using a value of 230V (i.e., 15 percent higher than its required battery voltage) as a reference or grid voltage and boost converter is set as 345V from the input voltage, based on the output voltage Va as 483V. Similarly, the charging sides required battery voltage is set at 420V, thus using boost converter voltage required to charge the charging sides battery is set at

483V, the output current Ia at 30A. Then, the values of resistance, the critical inductance, the duty cycle and the capacitance value can be calculated from the below mentioned equitation's (3) and (4) accordingly, where Va represents output voltage ripple. The values to design the circuit are taken in order to requirement parameters.

Resistance (R) = Va / Ia (1)

Duty cycle (k) = 1-Vo / Va (2)

Inductance (Lc) = 2kR (1-k) / (2fs) (3)

Cmin = I k / (fsVa) (4)

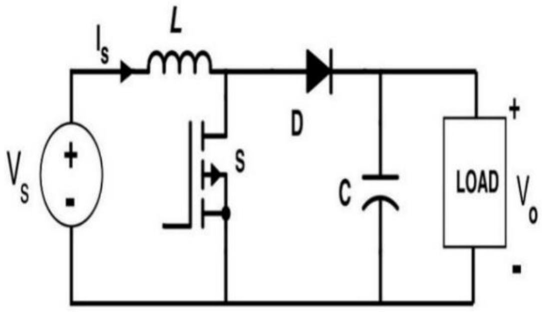


Fig. 4: Boost Converter Circuit

C. Charging algorithm of Li-ion battery:

The main components of Li-ion battery are 2 electrodes separated by an insulating sheath. Both positive and negative electrodes and insulating sheath are placed in electrolytes containing Li ions particles. Li ions are inserted into electrodes during charging process, during discharging process ions are extracted from the electrodes. Some Li ion batteries make use of liquid as well as solid electrolytes. During charging and discharging of the battery, this process followed by the oxidation of the electrodes. In [7], after charging process maximum energy can store into EVs battery depends on the charged ions spread into two different electrodes.

The commonly and most widespread used charging method for lithium-ion batteries is CC/CV charging method. CC/CV charging method is less complex reducing the hardware complexity and requirements and has less cost due to reduced hardware requirements. But in thesis paper we used only CV method. In reference paper [5] this method, first the battery is charged up to a present value using a constant voltage. When battery voltage reaches the present value the charging current is reduced gradually whereas keeping the charging voltage constant at present voltage. Battery charging ceases when the charging current reaches a predetermined small value. While the battery is charged in CV mode the charging current is gradually reduced. The battery charging ceases when the charging current reduces to 1% of total battery current capacity.

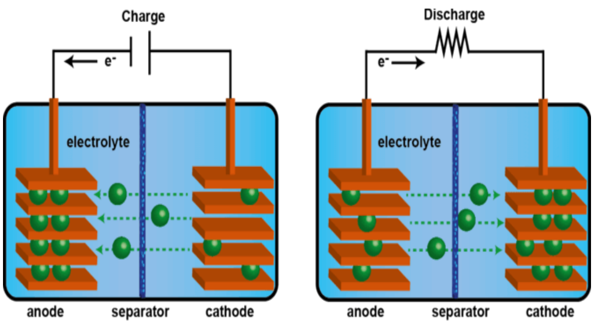


Fig. 5: Charging of Li ion Batteries

IV. PROPOSED WORK

Fast charging infrastructure of EVs battery circuit is used for charging the EVs battery with the help of charging post battery. When the load demand is very less, the charging station side battery will get charged during the night time. So that we can charge the battery with less cost.

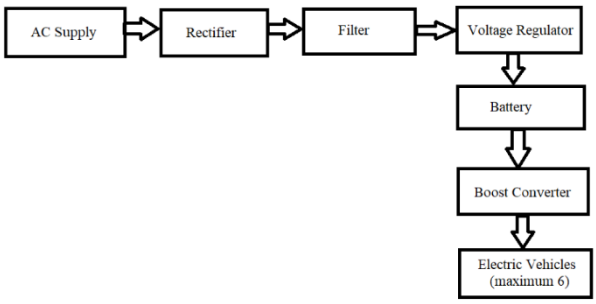


Fig. 6: Fast Charging Infrastructure

A. Simulation of Proposed Work:

Automatic charging control algorithm shown in simulation, where control circuit design and logic are carried out with help of the Sparten-6 FPGA board. Here we can used maximum 6 vehicles charged at a time. So, we can design 3 slide buttons for the arrival of car events and another 3 slide switch buttons for the selection of the destination i.e., measuring of SOC of EVs.

In this works we connected the three potentiometers i.e., voltage regulator which resembles the car batteries, by varying the potentiometer we can change the SOC of the potentiometer.

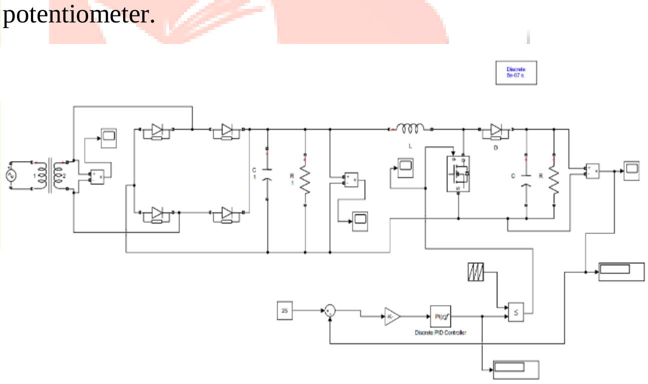
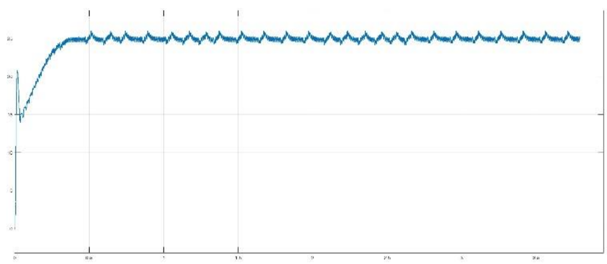


Fig. 7: Simulation of Proposed Work

B. Simulation Results:

Boost convertor output-



Voltage →

Fig. 8: Output voltage obtained at Boost Convertor

C. Control Circuit Charging Process:

- Charging process for EV 1:
  In [6], two cars are arrival at charging station among two vehicles car 1 has more SOC when compared to

another car. Then charging process is taking place at station 1. It will continue until the required SOC is reached. We can see that once the EV battery reaches the required SOC the charging process has stopped at the charging post side and relay will trip down.

- Charging process for EV 2:
  We can see the once the EV battery reaches the required SOC the charging process has stopped at the charging post side 2 and relay will trip down. So, the charging process is taking place in the post 2 and it will continue until the required SOC is reached.
- Charging process for EV 3:
  At charging post 3, we can see that once the EV battery reaches the required SOC the charging process has stopped at the charging post side 3 and relay trip down. Then three cars are present in charging post among three vehicles car 3 has more SOC when compared to another car. So, the charging process is taking place in post 3 and it will continue until the required SOC is reached.

D. Automatic Charging Control Algorithm:

In ([8]-[12]), the control design and logic follow the steps outlined below are

- In the 2nd steps the trip will be generated means total distance to be travelled and time measures.
- In this step identify the state of charge that is required to complete the entire trip and it is given to the system.
- Next step, the arrival of car events will be noted and information will be sent to the system.
- Compared the SOC of different arrival vehicles and first refer the greater SOC of the car is chosen for the trip.
- In this step SOC of the vehicle and required SOC of the vehicle is compared.
- If the SOC of the vehicle is sufficient then the process is terminated and vehicle is ready for trip i.e., discharging process. If SOC is not sufficient then the vehicle charging process will takes place.

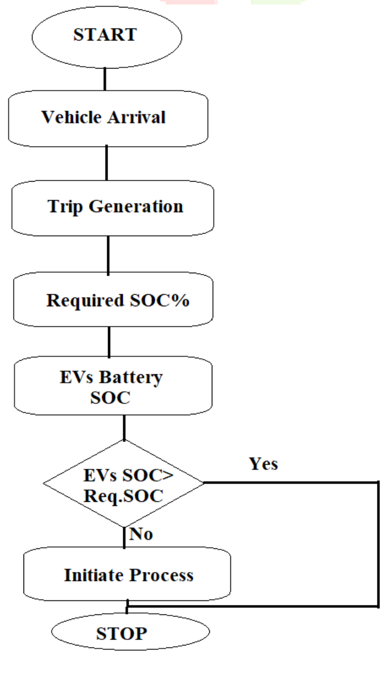


Fig. 9: Flow chart for automatic charging control algorithm

V. CONCLUSION

Thus, an automatic fast charging algorithm of electric vehicle is developed based on SOC of vehicles, design optimization results, increasing the charging power and decreasing the battery capacity and coil length lead to the most cost-effective design solution. Sizing of power electronic components is done to suit requirement for six vehicles. According to the charging characteristics of lithium-ion battery, a suitable charging method is proposed. This method slows down the decay of power battery and extend the cycle life of battery. It is still applicable different/larger network. As long as the vehicles routes are known, the potential locations for the fast charging will be defined on these routes. And the algorithm will be able to optimize the design parameters based on pre-defined objectives and constraints.

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