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Simulation Study of DC Fast-Charging Electric Vehicles

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Abstract: Electric Vehicles (EVs) are promising individual means of transportation in the future, providing local emissions-free, quiet, resource-flexible mobility. However, there is a weakness of EV where it's the recharging time of EV. This study proves charging time of EVs can fully recharge in less than 30 minutes. This simulation study was performed using MATLAB Simulink version 2022a with a battery capacity of 75kWh. The method applied for this study is recharging using the constant voltage (CV) technique and using a Simulink block. The supply source for MATLAB Simulink uses using three-phase source. To observe the charging time of a DC Fast Charging Electric Vehicle Battery, perform less than 30 minutes. Accordingly, this simulation study proves the time of recharging an EV battery.

Keywords: Electric Vehicles, DC Fast Charging, MATLAB Simulink

1. Introduction

Electric Vehicles (EVs) are promising individual means of transportation in the future, providing local emissions-free, quiet, resource-flexible mobility [1]. Compared to gasoline-powered vehicles, Electric Vehicles can significantly reduce greenhouse gas emissions, driver energy costs, and reliance on imported oil [2]. In general, EV charging at home or work can be done in normal charging mode. Electric vehicles also can be charged on fast charging mode at Level 1 and Level 2, or the installed Fast Charging Station [3]. The number of charging points for Electric Vehicles needs to be increased to address support for the electrification of road transport and potential user concerns. However, increasing the number of charging points may not solve all infrastructure needs. The timing of billing requirements can lead to customer satisfaction issues and fear of waiting. From the short charging time, rapidly changing technologies have been attracting attention recently, and Fast Charging Station is expected to be the important job to spread of Electric Vehicles soon [4] Currently, Electric Vehicles have three common charging options [5]. The level 1 charge takes place at the customer's site. Level 1 charging usually takes 1-1.4 kW single phase of the resident unit to charge their Electric vehicle's battery at night.

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The second charging option usually uses a Level 2 AC charger found in public parking lots. This type normally supplies 3.9-19.2 kW of power to a stationary vehicle. The third option, which is level 3 fast charging able to charge 50 kW to 350 kW speed of the direct current [6]. A 50-kW high-speed model is able that provide enough charge to cover a range of 100 miles in 30 minutes. One of the important parts of an Electric vehicle is the charging port and the charging socket. Table 1 shows the comparison of the Charging Electric Vehicle level from level 1 to level 3 which is DC Fast Charging. The DC fast charging is the fastest compared to Level 1 and Level 2. This study aims to perform a simulation on DC fast charging Electric Vehicles. This study project is to be able to lower the charging time to less than 30 minutes. MATLAB Simulink will be used to design and simulate the Fast-charging Electric Vehicles Station Simulation. The purpose of this project is to prove the charging time at the station is less than 30 minutes.

Table 1: The comparison of Charging EV Level

Charging EV Level	Level 1	Level 2	Level 3
power supply type	AC	AC	DC
charging rate	1-1.4 kW	3.9-19.2 kW	50-350kW
Charging Time	20-20 hours	8-10 hours	30 minutes-1 hours

2. Materials and Methods

This section discusses the basic processes of project work including the chosen materials, software, and methods used as well as covers the detailed explanation of simulation developed using MATLAB for the Simulation study of DC Charging Electric Vehicles.

2.1 Software MATLAB Simulink

Table 2 shows the MATLAB Simulink blocks used to simulate DC Fast Charging Electric Vehicles. This table shows the complete Simulink block name applied to the Simulation Study. The power of charging rate for this simulation study is 231kWh. The input value parameter for this Study applies the value indicated in Table 3. MATLAB Simulink block configuration is shown in Figure 1.

Table 2: Parameter specification for MATLAB Simulink block

Parameter	Simulink Block
Power Source	Three-Phase Source
Transformer	Three-Phase Transformer
AC/DC Converter	Three-Phase Converter
Filter	Inductor & Capacitor
Electric Vehicle Battery	Battery Li-ion
Electric Vehicle Battery Controller	Ideal Switch, Sum & Constant

Table 3: Simulink Input Parameter

Parameters	Value
Phase-to-phase voltage (Vrms)	25k
Frequency (Hz)	50Hz
3-phase short-circuit level at base voltage(VA)	1200MVA
X/R ratio	8
Inductance L (H)	1m
Capacitance C (F)	1n
battery capacity	75kWh
Battery time constant	1s
SOC	20%

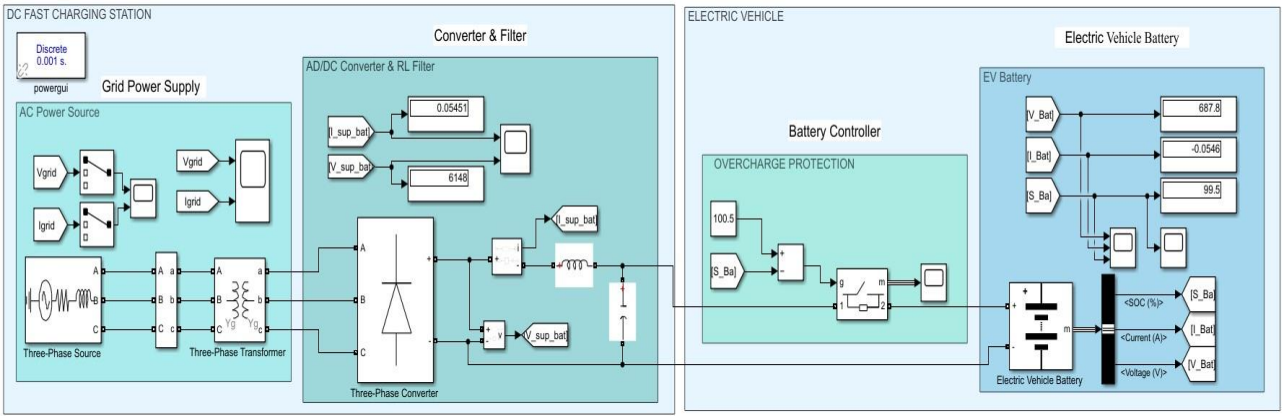

Figure 3: DC Fast Charging Station & Electric Vehicle Circuit Simulink

2.2 Equations

The calculation for the input value of the Electric Vehicle Battery can be calculated by using Equation 1. The calculation value is applied at the Battery Simulink block as the capacity value. Equation 2 is applied to calculate the power charging rate for the Electric Vehicle power.

$$Ah = kWh \div V \times 1000 \qquad Eq.1$$

$$Power\ EV = Voltage \times Current \qquad Eq.2$$

3. Results and Discussion

The results and discussion section presents the simulation result of DC Fast Charging Electric Vehicles data and analysis of the study. By implementing the parameter calculated and the MATLAB Simulink block the simulation can be performed.

3.1 DC Fast Charging Electric Vehicles

This system is divided into 2 parts the first part is the supply station called the DC Fast Charging Station and the second part is the consumer of the Electric vehicle Battery. These 2 parts can be described by referring to Figure 1. In the DC fast charging station, there are two combinations to complete the requirement of the station, grid power supply and converter and filter. The second part is

the electric vehicle battery where the energy store is at 75 kWh capacity. Figure 3 shows the result of this simulation study describing the Electric Vehicle Battery charging. The third graph shows the state of charge (SOC) from 20% to 99.9%. The first and second graphs describe the value of battery voltage and battery current. Implementing constant current (CC) technique Electric Vehicle Battery able to recharge in shorter than 30 minutes. Figure 2 shows the graph in detail of EV Battery charging from 20% to 99.9%.

The full circuit Simulink DC Fast Charging Electric Vehicle runs in MATLAB Simulation for the 1300s. The DC Fast Charging Electric Vehicle Simulink runs for 1100s which equals 18.33 minutes to fully charge the electric vehicles from 20% to 99.9%. The MATLAB Simulink runs actual 1300s to show the working principle of a Battery Controller Electric Vehicle to cutoff current and voltage supply. As a result, the Electric Vehicle Battery is protected from being overcharged.

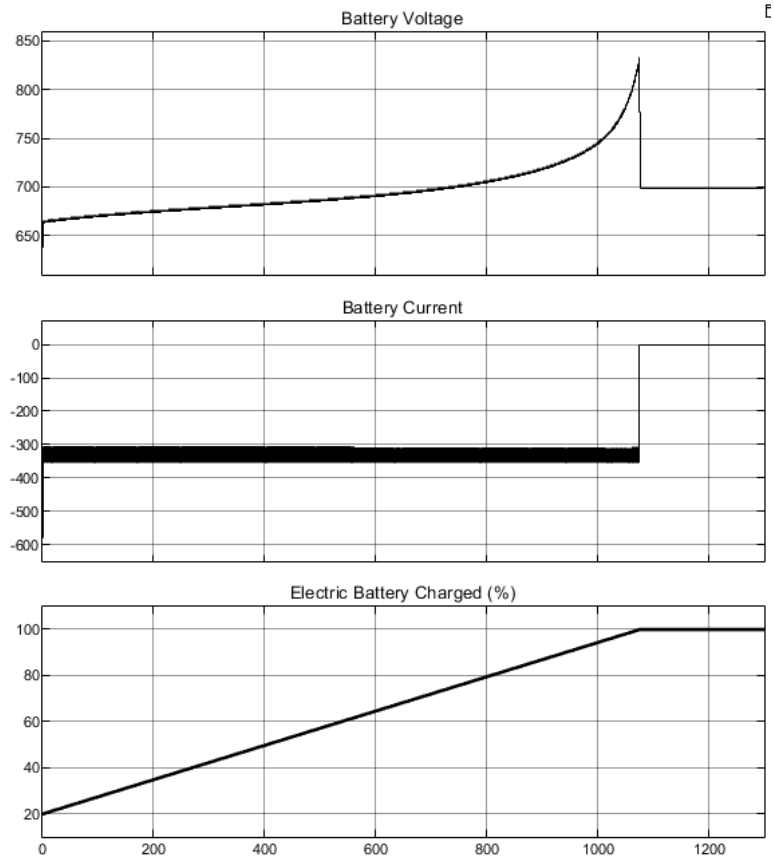

Figure 2: Electric Vehicle Battery Measurements

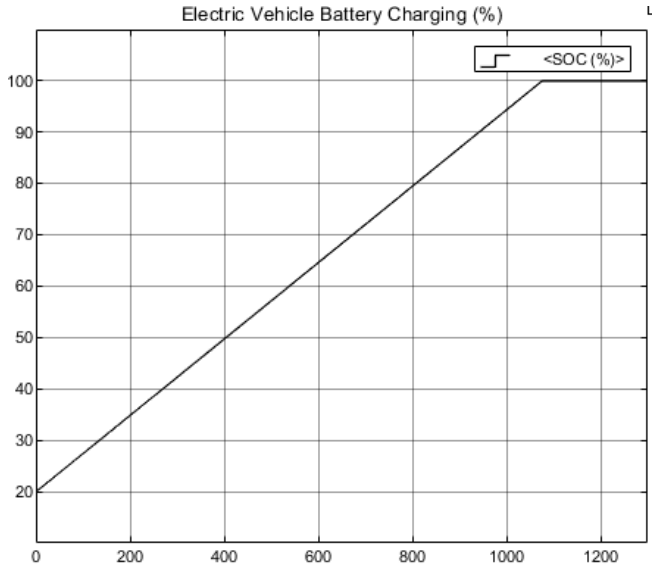

Figure 3: State of Charge (SoC) Electric Vehicle Battery capacity in percent.

4. Conclusion

Using MATLAB Simulink Version 2022a the Simulink block is consumed to generate the simulation which is a Three-Phase source, Three-Phase transformer, Three-Phase converter, inductor, and capacitor. These Simulink components work as the supply for the DC Fast Charging Station. The Battery model, Ideal switch, sum operation and constant Simulink block work as the Electric Vehicle Battery and battery controller. This study was able to improve the charging time to 18.33 minutes from 20% state of charge to 99.9%. The charging rate of Simulink DC Fast Charging Electric Vehicle Station is 231kWh with 660V voltage and 350A current. At the same time, the battery capacity for the Electric Vehicles Battery is 75kWh. The Electric Vehicle Battery Controller works to control the supply voltage and current from the DC Fast fast-charging electric Vehicle Station to the Electric Vehicles Battery. The Battery controller cuts off the supply when the battery is 99.9% charged. The main purpose of this objective is to protect the Electric Vehicle Battery from overheating caused by overcharging.

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