DESIGN AND SIMULATION OF AN OFF-BOARD DC FAST CHARGING STATION FOR ELECTRIC VEHICLE BATTERY

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DEDICATION

This project report is dedicated to my “Father” and “Mother” who always taught me to embrace each and every situation in life.

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ABSTRACT

Conventional fossil fuel-driven vehicles have caused acute environmental pollution. This demands the obligation of developing automotive industries that manufacture vehicles with lower carbon footprint impact on the environment. In the light of this need, electric vehicles (EVs) appear to be the best-suited alternatives to the conventional internal combustion (IC) engine. Despite having environmental benefit, electric vehicles charging creates a negative impact on the power grid. In this project, the unidirectional off-board level-3 EV charger was designed and simulated in Matlab/Simulink. This off-board charger has been divided into two parts. The first part is AC-DC converter where this part is controlled using voltage control approach to ensure standard grid voltage can be smoothly maintained, and to maintain the DC-link voltage at the constant level. The second part comprises the DC-DC converter, which functioning to ensure the battery can be charged within a specified limit using a constant current/constant voltage approach. From the executed simulation, it can be concluded that the proposed off-board EV charging station for 4 EVs units has been successfully designed and developed. As outcomes, the AC grid voltage has been successfully maintained its smooth sinusoidal waveforms even at full-load conditions. So does with the AC grid current and voltage where the total harmonic distortion (THD) level for both signals is within the permissible limit under the IEEE Standard 519-2014 requirements: under 8% for the bus voltage and under 5% for the current. When the number of EV unit charged is increases up to 4 units, current total harmonic distortion also increases. However, the AC sinusoidal grid voltage can be still smoothly maintained. The DC-link voltage has been also successfully maintained at the 800V constant level. For the battery safety condition, charging can be executed as required without overheating the battery.

ABSTRAK

Kenderaan berasaskan bahan bakar fosil konvensional telah menyebabkan pencemaran alam sekitar yang teruk. Ini menuntut kepada pengembangan industri automotif yang mampu mengeluarkan kenderaan dengan kesan jejak karbon yang lebih rendah terhadap alam sekitar. Berdasarkan keperluan ini, kenderaan elektrik (EV) kelihatannya merupakan alternatif yang paling sesuai untuk enjin pembakaran dalaman konvensional (IC). Walaupun mempunyai faedah yang lebih baik terhadap persekitaran, pengecasan kenderaan elektrik menimbulkan kesan negatif terhadap sistem grid kuasa. Dalam projek ini, pengecas EV berjenis "off-board" telah direka dan disimulasikan menggunakan perisian Matlab/Simulink. Pengecas "off-board" ini telah dibahagikan kepada dua bahagian. Bahagian pertama adalah penukar AC-DC di mana bahagian ini dikendalikan menggunakan pendekatan kawalan voltan untuk memastikan voltan grid standard dapat dikekalkan dengan lancar, dan untuk mengekalkan voltan pautan DC pada tahap yang tetap. Bahagian kedua terdiri daripada penukar DC-DC yang berfungsi untuk memastikan bateri dapat dicas dalam had yang ditentukan menggunakan pendekatan arus/voltan tetap. Dari simulasi yang dilaksanakan, dapat disimpulkan bahawa stesen pengisian EV "off-board" untuk 4 unit EV telah berjaya direka dan dimodelkan. Sebagai hasilnya, voltan grid AC berjaya mengekalkan bentuk gelombang sinusoidal yang bersih walaupun pada keadaan beban penuh. Begitu juga dengan arus AC dan voltan di mana tahap gangguan harmonik total (THD) untuk kedua-dua isyarat berada dalam had yang dibenarkan di bawah syarat IEEE Standard 519-2014: di bawah 8% untuk palang voltan dan di bawah 5% untuk arus. Apabila jumlah unit EV yang dicas meningkat hingga 4 unit dalam masa yang sama, jumlah keseluruhan gangguan harmonik juga meningkat. Walau bagaimanapun, voltan grid sinusoidal AC masih dapat dikekalkan dengan baik. Voltan pautan DC juga berjaya dikekalkan pada tahap tetap 800V. Untuk keadaan keselamatan bateri, pengecasan dapat dilakukan seperti yang diperlukan tanpa memanaskan bateri.

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LIST OF ABBREVIATIONS

ICE	-	Internal Combustion Engine
CHG	-	Green House Gas
PHEV	-	Plug-in Electric Vehicle
HEV	-	Hybrid Electric Vehicle
BEV	-	Battery Electric Vehicle
EV	-	Electric Vehicle
IEC	-	International Electrotechnical Commission
SAE	-	Society of Automobile Engineers
SOC	-	State of Charge
SOH	-	State of Health
FCEV	-	Fuel Cell Electric Vehicle
IEA	-	International Energy Agency
EVSE	-	Electric Vehicle Supply Equipment
AC	-	Alternative Current
DC	-	Direct Current
PI	-	Hysteresis Controller
PLL	-	Phase Locked Loop
PCC	-	Point of Common Coupling
SPWM	-	Sine-wave Pulse Wave Modulation

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CHAPTER 1

INTRODUCTION

1.1 Research Background

In recent years, technological advancement triggered electric energy demand. Majority of the energy is produced by burning fossil fuels. This burning causes greenhouse gases (GHG) emissions, which are harmful to the environment. In present days, the GFG emissions have reached a severe stage and its effects are eye-catching, such as a rise in temperature globally, large icebergs melting, and an increase in natural disasters. The matter will worsen if the necessary measures are not taken. In this regard, the International Energy Agency (IEA) has set a guideline for the energy sector to limit the global mean of rising temperature, which is set below 2°C by 2050 [1]. It is estimated that the GHG emission will be doubled by 2050 if the energy sector does not follow the guideline. According to the statistics in 2010 by IEC, transportation sector generated 23% GHG emission [1].

Over the years, several initiatives were accounted to curb the emissions from the transportation sector. The major goal is to lower the rate of carbon footprint by establishing new fuels and adapting green technologies for vehicles so that vehicles' performance can be increased. One of the prominent ways which comes with several benefits is to electrify transportation. Electric vehicles (EVs) can play a major role in many aspects, such as improving energy stability by expanding sources of energy, developing modern industries will eventually boost economic growth, and also reducing tailpipe emissions will lower the environmental pollution. Moreover, EV performance better than internal combustion engine (ICE) vehicles because of the efficient power train and electric motors [2].

Nowadays, governments are adopting numerous strategies, program, and policies for the wide acceptance of electric vehicles. Subsequently, governments took some steps to promote EVs such as subsidising the buying cost of EV, constructing charging stations and growing public understanding of the benefits of EVs. According to the report in Global EV Outlook 2020 by IEA, the global electric car stocks were 7.2 million in the year 2019. It means electric cars took 2.6% of the global car sales [3]. Besides that, as the EVs technologies are progressing, the market for this industry is expanding.

The continuous development of EV technologies is a key factor in improving the performance of EVs and ensuring their competitiveness. Recently, the manufacturers are focusing to develop the technologies of EVs drive train, battery, and charging infrastructure. Different types of drive train configurations can enhance fuel economy and also improve the vehicle mileage because of using a high-performance electric motor. Likewise, battery technology developed from lead-acid to nickel and finally to the lithium-ion battery. The reasons behind this development are to obtain high energy density, high power density, lightweight, cheap, reliable, and sustainable storage technology for the battery [4]. Charging infrastructure is the charging point for EVs. Initially, it started with AC supplied slow chargers and now DC fast charging station is evolved, which provides fast charging so that range anxiety issues can be solved.

EV produces zero CHG emissions, which is environmentally friendly. Nevertheless, EVs use electric power generated from the grid and the method of generating electricity produces emissions of greenhouse gas. So, the EVs base environmental impact depends on the electricity source. Thus, the renewable energies are broadly utilised lately and have encouraged EVs to become more environmentally friendly than traditional ICEVs [5]. Integrating the charging station to the grid for EV charging creates a negative impact on the grid. The predicted problems related to EV charging are voltage drop, equipment overloading, phase unbalance, harmonics, and increase in power demand, system losses, and stability issues [6].

Although EVs have been a recent development in the transport field, there are, of course, challenges to be met, such as the cost of batteries, the interconnection of charging stations, charging strategies and the impact on the grid. These problems need to be encountered by researchers and EV manufacturers in order to globalise this kind of invention for the transportation sector.

1.2 Problem Statement

The performance of EV depends heavily on factors such as driving range, fuelling convenience, and expense [7]. Currently, not all EV models accept all charging levels, nor do all public charging stations have charging facilities at all power levels. This makes it impossible for EV users to locate convenient charging stations.

The standards for manufacturing charging equipment are not common globally. In order to choose the best option for a given application, the different aspects of electrical vehicle charging systems, including its requirement and standard, need to be understood and deeply clarified to prevent from mis-chosen condition. Another important condition to be taken into account in the development of EVs is the battery charger, because the charging period and battery life are related to the features of the battery charger. The battery charger must be efficient, in high power capacity, reliable, cheap price, low volume and lightweight [8].

Plugging the electric vehicle into the grid creates different types of power quality issues. Typically, power quality issues such as harmonics, and voltage sag are observed during the charging process of EV. The aforementioned EV charging problem must be addressed to ensure secure operation of grid.

1.3 Research Objective

The research work has the following specific objectives:

(a) To design and simulate an Off-board EV charging station with two control strategies; Voltage Control (VC) and Constant Current-Constant Voltage (CCCV) charging approach.

(b) To ensure constant DC bus voltage is achieved while maintaining standard grid voltage during charging the EV battery.

1.4 Research Scope

The scopes of the research work are as follows:

(a) Off-board charging station is considered with unidirectional power flow, i.e., grid to vehicle (G2V).

(b) Proposed EV Station considered is four EV batteries.

(c) The process charging is divided into two parts of converters with their controller:

  (i) Part one is to convert from AC supply to DC supply regarding to the source is taken from the grid which is in AC supply.

  (ii) For part two DC to DC converter is connected to the battery.

(d) Maintaining total harmonic distortion (THD) for voltage within 8% following the IEEE 519-2014 standard.

(e) Fast charging the battery up to 80% SOC following SAE DC Level 3 standard.

(f) The modelling and simulation are conducted using MATLAB/Simulink.

1.5 Research Outline

In the following chapter 2, literature reviews related to the works regarding the DC fast charging station for EV battery will be demonstrated. In the chapter, technology of EV development, including the EVs charging types, power levels, strategies adopted to improve the performance and its impact on grid will be presented. Chapter 3 describes about the designing method of EV charging station. The obtained results are presented and discussed in chapter 4. Finally, conclusion and recommendation of project are enlisted in chapter 5.

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