OPTIMAL DESIGN FOR MULTIPLE MODE CHARGING STATION WITH PI CONTROLLER USING PARTICLE SWARM OPTIMIZATION

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2017

To my beloved parents, wife and siblings

ACKNOWLEDGEMENT

I am indeed grateful to Almighty Allah for providing me opportunity and strength to commence and conclude my Master of Engineering (Electrical Power) at Universiti Teknologi Malaysia.

I would like to express my gratitude to my supervisor, Dr. Jasrul Jamani for his inspirational guidance and excellent supervision and encouragement throughout the duration of my work.

I would also like to thanks to my parents and my wife for always being there to support me at all times and for giving me the courage and strength to carry on this project. Thanks for their encouragement, love, and moral support also their willingness to spend their time and money for me.

I would also like to thanks to my colleagues who had given me the advice, courage, and support in completing this project. They are helping me a lot throughout this project and giving me their useful views and tips.

Last but not least, I would like to thank to all the lecturers who have been very friendly and helpful in providing necessary information for my project.

ABSTRACT

This project proposes a suitable design for charging station (CS) that can produce different charging categories (slow, medium, and high). The CS mode is based on power size, rated voltage levels, number of phases and rated current as well as charging time. The higher charging mode will require less time to complete the charging process as compared to lower charging mode. However, the integration of CS gives negative impact to the distribution system such as power loss and voltage profile. This is due to harmonic that produced from non-linear load of CS. Thus, this research focusing on the analysis of the effect of harmonic on different charging categories (slow, medium and high). The different mode of CS can be obtained by varying the value of pulse width in pulse generator at the buck converter. Next, the suitable universal design for a passive filter is proposed to reduce harmonic distortion based on design CS. A closed loop system is introduced by implementing PI controller in order to reduce the error between the output of CS with output demand. In term of analysis, the values of proportional constant (Kp) and integral constant (Ki) in this project had been obtained by using Particle Swarm Optimization (PSO). All the circuits are designed, simulate and analyses by using MATLAB/Simulink. From the result, it is proved that the installation of single tuned passive filter at 5th order and 7th order can reduce both THDv (2.94%-5.26%) and THDi (4.83%-9.11%). Besides that, closed loop system shows better performance as compared to open loop system in term of THD level and fulfill output demand. The results also fulfill the recommendation of IEEE 519 power harmonic standard.

ABSTRAK

Projek ini mencadangkan reka bentuk yang sesuai untuk stesen pengecas (SP) yang boleh menghasilkan pelbagai kategori pengecas (perlahan, sederhana dan tinggi). Kategori SP ini dibuat berdasarkan kepada jumlah kuasa, tahap nilai voltan, jenis fasa, tahap arus dan juga tempoh masa yang diambil untuk mengecas. Kategori pengecas tinggi memerlukan masa yang singkat untuk melengkapkan proses pengecasan berbanding pengecas kategori perlahan. Walau bagaimanapun, penyambungan SP memberi kesan negatif kepada sistem pengagihan seperti kehilangan kuasa dan taraf voltan. Masalah ini berlaku disebabkan oleh harmonik yang dihasilkan daripada SP dimana beban yang digunakan adalah tidak linear. Oleh itu, kajian ini memberi tumpuan kepada analisis kesan ke atas kategori pengecasan yang berbeza (perlahan, sederhana dan tinggi). Kategori SP yang berbeza boleh diperolehi dengan mengubah nilai lebar denyut dalam penjana nadi di penukar penurun. Seterusnya, reka bentuk penapis pasif yang umum dicadang untuk mengurangkan herotan harmonic berdasarkan SP yang di reka. Sistem gelung tertutup diperkenalkan dengan melaksanakan pengawal PI untuk mengurangkan ralat di antara keluaran SP dengan keperluan keluaran. Dari segi analisis, nilai-nilai yang berkadar malar (Kp) dan keseluruhan malar (Ki) dalam projek ini telah diperolehi dengan menggunakan Pengoptimuman Kerumunan Zarah (PSO). Semua litar direka, di simulasi dan di analisis dengan menggunakan MATLAB / Simulink. Hasil keputusan, membuktikan bahawa pemasangan tunggal penapis pasif pada harmonik turutan ke-5 dan turutan ke-7 boleh mengurangkan kedua-dua nilai THDv (2.94% -5,26%) dan THDi (4.83% - 9,11%). Selain itu, sistem gelung tertutup menunjukkan prestasi yang lebih baik berbanding dengan sistem gelung terbuka dari segi tahap THD dan memenuhi permintaan keluaran. Hasil keputusan juga memenuhi piawaian bagi IEEE 519 kuasa harmonik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CS	-	Charging station
EV	-	Electric vehicle
OS	-	Overshoot
PSO	-	Particle Swarm Optimization
SSE	-	Steady state error
THD	-	Total harmonic distortion
Ts	-	Settling time
US	-	Undershoot

LIST OF SYMBOLS

c1	-	Cognitive coefficient
c2	-	Social coefficient
D	-	Duty ratio/ Pulse width
Gbest	-	Global best (overall) for particle
i	-	Particle Number
I_L	-	Full load current
I_{sc}	-	Short curcuit current
Kp	-	Proportional gain
Ki	-	Integral gain
k	-	Iteration
Pbest	-	Individual best for particle
r1 & r2	-	Random parameter
${v_i}^k$	-	Particle Velocity
ω	-	Inertial Weight
${x_i}^k$	-	Particle Position

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

The world still heavily depends on conventional non-renewable energy such as fossil fuels in producing the useful energy. Based on International Energy Agency's Key World Energy Statistics 2014, 63.7% from global crude oil was spent for transportation sector [1]. Due to a prospective shortage of fossil fuels as well as environmental issues on CO_2 emission, researchers and vehicle industries have started to focus on the electrical vehicle (EV) system in order to find alternative ways to overcome these issues [2-4]. There are many advantages of EV compared to traditional combustion vehicle, especially on environmental issue, more efficient motor, and less cost of maintenance [2].

The increasing number of EV has led to increase in a number of charging station (CS). However, the integration of CS gives negative impact to the distribution system such as power loss increased and violation in voltage profile [5-7]. This is due to the harmonic produced from a non-linear unit of CS during charging process. The non-linear load will cause non-sinusoidal and distorted current when it is connected to the grid. This distorted current will give impact to the public networks which are designed to operate with a sinusoidal voltage [4, 5]. Recent research shows that the high power DC in CS give a larger potential impact to distribution system compared to the normal power of CS [8].

In view of these shortcomings, mitigation of harmonics is very important in EV CS to avoid negative impact to the distribution system. The suitable design for a universal passive filter is proposed for harmonic mitigation. The passive filter connected in shunt configuration that is used in this research will not require overcurrent protection devices. Besides that, passive filters also provide reactive power at system operating frequency. Thus, it can improve power factor of the system.

This study will focus on design of CS that can produces three modes of charging operation. Besides that, a good passive filter will be installed to cater the harmonics produce from the CS. Lastly, PI controller also will be implemented in order to improve the performance of CS, where the gain values is obtained by using Particle Swarm Optimization (PSO).

1.2 Problem Statement

Based on the statistic portal, there are around 200,000 EVs use globally in 2013. In early 2016, the number of EV has increased to 1.3 million units and China aims to increase the stock of EV to about 11.9 million units by 2020. The increasing number of EV has led to increase the number of CS. Based on the simulation conducted by [9], the current drawn from the utility not follow the Europe standard that is expected to be fulfilled in commercial CS. Furthermore, this CS is designed in open loop system where pulse width at buck converter is adjusted manually in order to obtain different charging categories. Besides that, the current harmonics produce from the CS designed has violated the recommendation standard, especially for individual harmonics. Therefore, in this project, the improvement on the design of CS in term of closed loop system by implementing PI controller, where gain values proportional constant (Kp) and integral constant (Ki) is obtained from PSO algorithm. In addition, this project also improves the design of CS by implementing a passive filter to eliminate the harmonics distortion as well as improving the power factor correction for CS.

1.3 Project Objectives

The objectives of this research project are as follow:

i. To analyse the effect of different charging categories (slow, moderate, and high) on the harmonic injection to the CS.

ii. To design suitable passive filters that can be used to all types of CS for harmonic mitigation.

iii. To design closed loop system by implementing PI controller and PSO implementation to improve the performance of CS.

1.4 Scopes of Study

The scopes of this project are as follow:

i. Only three categories of charging station (slow, moderate and high) at the three-phase system (400 V) will be considered in the analysis.

ii. One load (lithium-ion battery) with the capacity of 25 Ah is considered in the simulation.

iii. Matlab/ Simulink will be used to design the desired circuit, analysis and to achieve the objectives of this project.

iv. The IEEE 519 harmonic standard will be used to validate the results.

1.5 Project Outline

This project paper consists of five chapters. Chapter 1 is the introduction of this project, which explains briefly the purpose of this project. The relevant issues and reasons of conducting the study are described in this chapter. There are several parts in this chapter, which include of background information, problem statement, objectives of the study, and the scope of this project.

Chapter 2 discusses on the literature review that more focus on the theoretical information that related with the study. It also discusses and reviews several published paper such as journal and conference paper conducted by previous researchers. This chapter consists of several parts such as topology of CS, multilevel CS control method, an overview of PSO algorithm, harmonics distortion, and harmonics mitigation.

Chapter 3 discusses the design and simulation conducted in this project. This chapter describes the method to design CS for different categories. Next, the suitable universal design for the passive filter that can be used to all types of CS is determined to reduce harmonic distortion. After that, closed loop system will be introduced by implementing PI controller in order to improve the performance of CS. In this project, the values of Kp and Ki is obtained by implementing PSO technique. Apart from that, it also describes the related theoretical information and mathematical calculations for several parameters of the proposed model.

Result and discussion of this project are presented in Chapter 4. Based on the simulation that has been done in Chapter 3, the analyses of the result is carried out to analysis the effect on different charging categories to the harmonic injection. In addition, several analyses also are conducted to investigate the effectiveness of the use of the passive filter in eliminating the harmonics distortion. Lastly, this chapter also describes the improvement of CS performance after implementation of closed loop system.

Last but not least, Chapter 5 which is the final chapter of this project paper. The chapter is divided into two parts which consist of the conclusion of the overall study and recommendation for future works related to the study.

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