MATLAB BASED MODELING AND SIMULINK PACKAGE FOR DC-DC BOOST CONVERTOR TO ENHANCE LEARNING PROCESS OF POWER ELECTRONICS.

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ABSTRACT

In this study, DC-DC boost converter Matlab Simulink Package has been developed and tested for the enhancement of learning process within academic course of power electronics. Respondent for this research were chosen randomly from Faculty of Electrical & Electronic Engineering, Tun Hussein Onn University of Malaysia. Aim of this study is to figure out and see the effectiveness of DC-DC boost converters Simulink package for the enhancement of learning process of Power electronic course. A Pre-research statistical analysis based on the response of concerned students acquired through a relative questioner is employed to affirm the need of this simulation package. Analysis for this study has been verified by using Statistical Package for Social Science (SPSS) Version 20.0 software. Afterwards, a simulation package as required has been developed accordingly to test and illustrate the operation of DC-DC boost convertor using open-loop, Proportional integral derivative (PID) controller and Fuzzy logic controller topologies. Finally, a post-research questioner was also floated through same respondent population in order to evaluate and assess the effect and significance of the designed simulation package. It was observed through the statistical analysis of the afore mentioned post research questioner that, the use of simulation based package regarding the enhancement of learning proved to have a significant effect. Expect this study findings will be one of the catalysts in strengthening improve the instructional methods by using simulation software’s in Power electronics and engineering courses.
ABSTRAK

Dalam kajian ini, DC-DC boost converter Matlab Simulink Package telah dibangunkan dan diuji untuk peningkatan proses pembelajaran dalam mata pelajaran kuasa elektronik. Responden bagi kajian ini telah dipilih secara rawak dari Fakulti Kejuruteraan Elektrik & Elektronik Kejuruteraan, Tun Hussein Onn Universiti Malaysia. Tujuan kajian ini adalah untuk mengetahui dan melihat keberkesanan DC-DC boost converter Matlab Simulink Package untuk menambahbaik proses pembelajaran mata pelajaran elektronik kuasa. Ujian sebelum (pre-research) untuk analisis statistik berdasarkan maklumbalas pelajar diperolehi melalui soal selidik untuk mengesahkan keperluan pakej simulasi ini. Di dalam kajian ini, penyelidik menggunakan perisian Statistical Package for Social Science (SPSS) versi 20.0. Selepas itu, pakej simulasi seperti yang dikehendaki telah dibangunkan dengan sewajarnya untuk menguji dan menggambarkan operasi DC-DC penukar rangsangan menggunakan open-loop, Proportional integral derivative (PID) controller dan Fuzzy logic controller topologies. Akhir sekali, ujian selepas (post-research) diapungkan melalui maklumalas responden untuk menilai dan menguji keberkesanan pakej simulasi yang direka. Melalui analisis statistik yang dilakukan dalam ujian selepas (post-research), penggunaan pakej simulasi mengenai peningkatan pembelajaran terbukti mempunyai kesan yang ketara. Diharapkan dapatan kajian ini akan menjadi salah satu pemangkin dalam meningkatkan kaedah pengajaran dengan menggunakan perisian simulasi ini dalam mata pelajaran kuasa elektronik dan bidang kejuruteraan.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER CONTENT</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>i</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>TABLE OF CONTENT</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF TABLE</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF ABBREVIATION</td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xviii</td>
</tr>
</tbody>
</table>

## CHAPTER 1 INTRODUCTION

1.1 Introduction                              1  
1.2 Problem Statement                         3  
1.3 Objective                                5  
1.4 Hypothesis                               6  
1.5 Importance of Study                      6  
1.6 Study Scope                              7  
1.6.1 Simulation Scopes on Matlab Package    7  
1.7 Study Restriction                        8  
1.8 ADDIE Model Of Instructional Design      8  

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction 13
2.2 Simulation-Based Learning 15
2.3 Pedagogical Philosophy 16
  2.3.1 Pedagogical Approach 16
2.4 Matlab simulation based learning 17
  2.4.1 Matlab Simulink for Power Electronics 18
2.5 DC-DC Converters 19
  2.5.1 Non Isolated DC-DC Converters 19
    2.5.1.1 Buck converter 19
    2.5.1.2 Boost Converter 20
    2.5.1.3 Buck-Boost Converter 21
    2.5.1.4 Cuk Converter 21
  2.5.2 Isolated DC-DC Converters 22
    2.5.2.1 Fly Back Converter 22
    2.5.2.2 Forward converter 23
    2.5.2.3 Functions of DC-DC converters 24
2.6 DC-DC converter switching 25
2.7 Advantages of DCM 28
2.8 Disadvantages of DCM 29
2.9 Boost Converter 29
  2.9.1 Analysis for switch closed (on) 31
  2.9.2 Analyses for switch open (off) 32
2.10 PID Controller 36
2.11 Fuzzy logic controller system 38
2.12 Fuzzification 40
2.13 Advantages of Fuzzy Logic Controller 45
CHAPTER 3 METHODOLOGY

3.1 Introduction 46
3.2 Flow chart for Design Study and Methodology 48
3.3 Sampling 49
3.4 Study Instruments 49
3.5 Pre-Research Questioner 49
3.6 Post-Research Questioner 51
3.7 Boost Convertor Parameters 52
3.8 Fuzzy Logic Controller and Its Operational Methodology 53
3.9 Rule Base 55
3.10 Data Analysis Procedure For Pre-Research 56
   3.10.1 Respondent Based On Gender 56
   3.10.2 Student Response On Pre-Research Questions 57
   3.10.3 Analysis Results Of Pre-Research Questioner 60
3.11 Reliability and Validity Analysis 61
3.12 Data Analysis Method For Post-Research Questioner 64
3.13 Conclusion 66

CHAPTER 4 RESULTS AND ANALYSIS

4.1 Introduction 67
4.2 Results And Findings 69
4.3 Objective 1: Development of Matlab Simulink Package.
   4.3.1 Analyze Phase 70
4.3.2 Design Phase 70
4.3.3 Development Phase 71
4.3.4 Implementation and Evaluation Phase 73

4.4 Objective 2: Investigate The Voltage Outputs 74
4.4.1 Analysis For Open Loop Boost Convertor 74
4.4.2 Analysis For Boost Convertor with PID 76
4.4.3 Analysis For Boost Convertor with Fuzzy 77

4.5 Objective 3: Comparison Between Outputs 80

4.6 Data Analysis Post-Research Questioner Section A 81
4.6.1 Data Analysis Based On Gender 82
4.6.2 Data Analysis Based On CGPA 83
4.6.3 Data Analysis Based On Education 84
4.6.4 Data Analysis Based On Learning Style 85

4.7 Data Analysis Post-Research Questioner Section B 86
4.7.1 Data Analysis Of Objective 4 87
4.7.2 Data Analysis Of Objective 5 88
4.7.3 Data Analysis Of Objective 6 89
4.7.4 Data Analysis Of Objective 7 90

4.8 Results Of Overall Mean and Standard Deviation 92

4.9 Hypothesis Analysis 93
4.9.1 Hypothesis 93
4.9.2 Coefficient Of Determination In Multiple Regression. 94

4.10 Comment Section Description 96

4.11 Conclusion 96
CHAPTER 5 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction 97
5.2 Discussion 98
  5.2.1 Respondent Background 98
  5.2.2 Ramification Of Matlab Simulink Package 98
  5.2.3 Learning From Matlab Simulink Package 99
  5.2.4 Response From Matlab Simulink Package 101
  5.2.5 Benefits Of Matlab Simulink Package 102
5.3 Analysis Indication 103
5.4 Conclusion 104
5.5 Recommendations 105
  5.5.1 Recommendation For UTHM 105
  5.5.2 Recommendation For Further Research 106

REFERENCES 107

APPENDICES 109
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>NO</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>ADDIE Model</td>
<td>9</td>
</tr>
<tr>
<td>2.1</td>
<td>The Basic Circuit Configuration of the Buck Converter</td>
<td>20</td>
</tr>
<tr>
<td>2.2</td>
<td>Basic Circuit of Boost Converter</td>
<td>20</td>
</tr>
<tr>
<td>2.3</td>
<td>Basic Circuit of Buck-Boost Converter</td>
<td>21</td>
</tr>
<tr>
<td>2.4</td>
<td>Basic Circuit of Cuk Converter</td>
<td>22</td>
</tr>
<tr>
<td>2.5</td>
<td>Basic Circuit of Fly-Back Converter</td>
<td>23</td>
</tr>
<tr>
<td>2.6</td>
<td>Basic Circuit of Forward Converter</td>
<td>24</td>
</tr>
<tr>
<td>2.7</td>
<td>Switching ON and OFF of DC-DC converter</td>
<td>26</td>
</tr>
<tr>
<td>2.8</td>
<td>$T_{ON}$ and $T_{OFF}$ pulse</td>
<td>26</td>
</tr>
<tr>
<td>2.9</td>
<td>Continuous Conduction Mode</td>
<td>27</td>
</tr>
<tr>
<td>2.10</td>
<td>Discontinuous Conduction Mode</td>
<td>27</td>
</tr>
<tr>
<td>2.11</td>
<td>$i_L$ and $V_L$ when inductor looks like short circuit</td>
<td>28</td>
</tr>
<tr>
<td>2.12</td>
<td>A Boost Converter Circuit</td>
<td>30</td>
</tr>
<tr>
<td>2.13</td>
<td>The Duty Cycle for Switching Period during Steady State</td>
<td>30</td>
</tr>
<tr>
<td>2.14</td>
<td>The Equivalent Circuit of Boost Converter When the</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Switch S Is Closed</td>
<td></td>
</tr>
<tr>
<td>2.15</td>
<td>Analysis for Switch Closed (on)</td>
<td>32</td>
</tr>
<tr>
<td>2.16</td>
<td>The Equivalent Circuit of Boost Converter When the</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Switch S Open</td>
<td></td>
</tr>
<tr>
<td>2.17</td>
<td>Analysis for Switch Opened (Off)</td>
<td>33</td>
</tr>
</tbody>
</table>
2.18 Control Methods for DC-DC Converters 36
2.19 Proportional-Integral-Derivative (PID) Controllers 37
2.20 Fuzzy Logic Controller Schematic 39
2.21 FLC Overall Structure 39
2.22 The Features of A Membership Function 40
2.23 (A) Triangular Membership Function Shape 42
2.23 (B) Gaussian Membership Function Shape 42
2.23 (C) Trapezoidal Membership Function Shape 42
2.23 (D) Generalized Bell Membership Function Shape 45
2.23 (E) Sigmoidal Membership Function Shape 48
2.24 Weight Average Method Defuzzification 54
3.1 The Overview of the Methodology Flow Chart of this Project 72
3.2 Block Diagram of Fuzzy Control System 72
4.3.3 (A) Screen Shot Of Open Loop 72
4.3.3 (B) Screen Shot Of PID 73
4.3.3 (C) Screen Shot Of Fuzzy Logic 73
4.6.1 Sprinkling Of Respondents Based On Gender 82
4.6.2 Sprinkling Of Respondents Based On CGPA 83
4.6.3 Sprinkling Of Respondents Based On Education 84
4.6.4 Sprinkling Of Respondents Based On Learning Style 85
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>NO</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Example of rule base</td>
<td>42</td>
</tr>
<tr>
<td>3.1</td>
<td>The value of all parameters can be determined as below</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Parameters and values for boost converter</td>
<td></td>
</tr>
<tr>
<td>3.10.2</td>
<td>Questions Analysis of Pre-Research Questions</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>(a),(b),(c),(d),(e),(f),(g)</td>
<td></td>
</tr>
<tr>
<td>3.11</td>
<td>Alpha Cronbach Level Of Reliability</td>
<td>61</td>
</tr>
<tr>
<td>3.11.1</td>
<td>Results From Validity Reliability</td>
<td>62</td>
</tr>
<tr>
<td>3.11.2</td>
<td>SPSS Reliability Analysis</td>
<td>63</td>
</tr>
<tr>
<td>3.12</td>
<td>Data Analysis Method</td>
<td>64</td>
</tr>
<tr>
<td>4.5</td>
<td>(A) The Features of A Membership Function</td>
<td>80</td>
</tr>
<tr>
<td>4.5</td>
<td>(B) Voltage Results From Open Loop</td>
<td>81</td>
</tr>
<tr>
<td>4.6.1</td>
<td>Sprinkling Of Respondents Based On Gender</td>
<td>82</td>
</tr>
<tr>
<td>4.6.2</td>
<td>Sprinkling Of Respondents Based On CGPA</td>
<td>83</td>
</tr>
<tr>
<td>4.6.3</td>
<td>Sprinkling Of Respondents Based On Education</td>
<td>84</td>
</tr>
<tr>
<td>4.6.4</td>
<td>Sprinkling Of Respondents Based On Learning Style</td>
<td>85</td>
</tr>
<tr>
<td>4.7</td>
<td>Ladell Mean Level</td>
<td>86</td>
</tr>
<tr>
<td>4.7.1</td>
<td>Objective 4</td>
<td>87</td>
</tr>
<tr>
<td>4.7.2</td>
<td>Objective 5</td>
<td>88</td>
</tr>
<tr>
<td>4.7.3</td>
<td>Objective 6</td>
<td>90</td>
</tr>
<tr>
<td>4.7.4</td>
<td>Objective 7</td>
<td>91</td>
</tr>
<tr>
<td>4.8</td>
<td>Overall Mean</td>
<td>92</td>
</tr>
</tbody>
</table>
4.9.2 Coefficient of determination Results
LIST OF SYMBOLS AND ABBREVIATIONS

μe - Degree of membership function of error
Δe - Degree of membership function of delta of error
u - Degree of membership function of voltage output
∨ - Maximum operator
O - Output of COG
∧ - Minimum operator
B - Bisector of Area
C - Capacitor
CCM - Continuous Conduction Mode
che - Change of Error
COG - Centroid of Gravity
D - Duty Cycle
DC - Direct Current
DCM - Discontinuous Conduction Mode
e - Error
FLC - Fuzzy Logic Controller
Fs - Frequency Switching
FKEE – Faculty of electrical and electronics engineering.
gaussmf - Gaussian Membership Function
KI - Integral gain
KD - Derivative gain
KP - Proportional gain
L - Inductor
MF - Membership Function
MOM - Mean of Maximum
MOSFET - Metal–Oxide–Semiconductor Field-Effect Transistor
NB - Negative Big
NS - Negative Small
PB - Positive Big
PID - Proportional Integral Derivative
PS - Positive Small
PWM - Pulse Width Modulation
R - Resistor
S – Switch
UTHM- University Tun Hussein onn Malaysia
VC - Voltage (Calculation)
Vo - Output Voltage
s - Kth - switching cycle Input Voltage
Vref- Reference output
ZE – Zero
UTHM-Universiti Tun Hussein Onn Malaysia
LIST OF APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A</td>
<td>Pre-Research Questionnaire</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>Post-Research Questionnaire</td>
<td></td>
</tr>
<tr>
<td>Appendix B</td>
<td>Statistical Analysis Data</td>
<td>120</td>
</tr>
<tr>
<td>Appendix C</td>
<td>Supporting Documents</td>
<td>134</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

1.1 Introduction

Power electronics is, by nature, a multi-disciplinary subject, and for any instructor a challenging course to teach. It is especially demanding course because of variety of topics, such as circuit analysis, signals and systems analysis, and control theory. It is a combination of hands-on experience and solid knowledge of theory provides an active learning environment that leads to successful learning and understanding process.

The use of simulation has always been a powerful tool for technology in all its various fields of application. Power Electronics course is essential for electrical and electronics engineers and it is included in the undergraduate and Postgraduate syllabus. An effective power electronics laboratory is expected to combine theoretical and experimental aspects of the topics by using state-of-the-art software/hardware tools. Sometime during experiment students face many problems in understanding of the procedure of experiment. For them simulation based demonstration of experiment is very useful especially in power electronic and some relevant courses.
DC to DC boost converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage) and boost converter (step-up converter) is a DC-DC power converter with an output voltage greater than its input voltage. They provide smooth acceleration control, high efficiency, and fast dynamic response. DC converter can be used in regenerative braking of DC motor to return energy back into the supply, and this feature results in energy saving for transportation system with frequent stop; and also are used, in DC voltage regulation (Rashid, 2004). In many ways, a DC-DC converter is the DC equivalent of a transformer. There are four main types of converter usually called the buck, boost, buck-boost and Boost converters. The main feature of a fuzzy controller is that it can convert the linguistic control rules based on expert knowledge into automatic control strategy. So it can be applied to control systems with unknown or unmodeled dynamics. (Ozdemir, 1997)

Mostly, the DC-DC converter consists of the power semiconductor devices which are operated as electronic switches and classified as switched-mode DC-DC converters. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters. Due to this unwanted nonlinear characteristics, the converters requires a controller with a high degree of dynamic response. Pulse Width Modulation (PWM) is the most frequently consider method among the various switching control method (J. Alvarez-Ramirez, Jan. 2001). In DC-DC voltage regulators, it is important to supply a constant output voltage, regardless of disturbances on the input voltage.

Currently, the control systems for many power electronic appliances have been increasing widely. Crucial with these demands, many researchers or designers have been struggling to find the most economic and reliable controller to meet these demands. The idea to have a control system in dc-dc converter is to ensure desired voltage output can be produced efficiently as compared to open loop system.
The focus of this research is the development of DC-DC boost converter Matlab simulink package by using fuzzy logic controller for enhancing the learning process of power electronic course. In this project, Matlab simulink package is used as a platform for students to understand the function of DC-DC boost converter. After the development of Boost converter Matlab Simulink will be test on UTHM, Faculty of electrical and electronics engineering students and then evaluate and analyze the effectiveness of this Matlab simulink package with the help of design Post-research questioner which will discuss in chapter 4 of this study.

1.2 Problem Statement

Power electronics is one of the essential course in engineering (electrical and electronics), and the main focus of this course on diploma and degree level on DC-DC boost convertors. DC-DC boost convertors are widely used in industrial applications according to the requirement of project. Firstly, most of the power electronics final year degree students of Electrical engineering they are facing problems during working on hardware without testing on simulation based software, that’s why they waste a lot of their money and time and sometimes they may damage expensive laboratory equipment’s of university and Polytechnics because they are working on hardware without any precaution and proper handling.

Secondly most of the students have different learning styles like auditory, visual and hands-on. Sometimes student they cannot understand on first attempt and sometimes because of improper material used in class might be the reason why students can’t perform well in exams. Students also might feel annoyed with the material used which will lead them to lose concentration and attention in the class. Many students they prefer visual and hands-on learning style rather than auditory or teacher center. For these type of students simulation based software’s are very useful and especially in electrical and electronics engineering students with the help of this simulation based software they can
repeat and redo their required experiment before working on hardware even the last year students of faculty of Faculty of Electrical and Electronic, UTHM are facing same problem in their experimental work which is analyzed from Pre-Research Questioner data of this research for the justification of this problem statement.

For enhancing the learning process of power electronics course, experimental work before working on hardware its better and effective to implement DC-DC convertor on Matlab simulink for sufficient learning outcome and also save costly electrical equipment. Developing the fuzzy controller is cheaper than developing a model based or other controllers for the same purpose. Proportional-Integral-Differential (PID) controllers have been usually applied to the converters because of their simplicity. However, the main drawback of PID controller is unable to adapt and approach the best performance when applied to nonlinear system. It will suffer from dynamic response, produces overshoot, longer rise time and settling time which in turn will influence the output voltage regulation of the Boost converter.

The implementation of practical Fuzzy Logic controller that will deal to the issue must be investigated. The Fuzzy control is a practical alternative for a variety of challenging control applications because Fuzzy logic control is nonlinear and adaptive in nature that gives it a robust performance under parameter variation and load disturbances. Fuzzy controllers are more robust than PID controllers because they can cover wider range of operating conditions than PID, and can also operate with noise and disturbance of different natures. Fuzzy logic is suited to low-cost implementations and systems of fuzzy can be easily upgraded by adding new rules to improve performance or add new features.
1.3 **Objective**

The objectives of this project are,

i. To develop a DC- DC Boost convertor Matlab Simulink package to enhance learning process of power electronics course.

ii. To investigates the voltage output for DC-DC Boost converter between open loop, PID controller and fuzzy logic controller through Matlab simulink package.

iii. To compare the output of close loop and open loop DC-DC boost convertor.

iv. To identify the ramifications of Boost convertor Matlab Simulink software package.

v. To analyze the Learning outcomes from Boost convertor Matlab Simulink software package.

vi. To analyze the response from Boost convertor Matlab Simulink software package.

vii. To identify the benefits of Boost convertor Matlab Simulink software package.
1.4 Hypothesis

$H_0$ : There is no significant change in the mean value of learning process of DC-DC boost convertors by using Matlab simulink package.

1.5 Importance of Study

i. To provide experience and the importance of simulation based power electronic course for final year degree student of electrical engineering.

ii. Students will directly involve in this study and they are final year degree students from Faculty of Electrical and Electronic Engineering (FKEE), UTHM.

iii. After the successful completion of this study, it might help various aspects. It can be used in Electrical Engineering Faculty (FKEE) and other Faculties for enhancing student’s simulation based engineering skills.
1.6 Study Scope

The scopes of this project is to simulate the proposed method of voltage tracking of DC-DC boost converter using Fuzzy controller with Matlab Simulink software for the enhancement of learning process of power electronic students. Analyses of the converter will be done for continuous current mode (CCM) only. The analysis only covered the output voltage based on reading on overshoot ratio, rise time, peak time and settling time. In this project, Matlab simulink package is used as a platform in designing the fuzzy logic controller. This Matlab simulink package is develop to study the dynamic behavior of DC-DC boost converters and performance of proposed controller for the enhancement of learning process of Power electronics students.

1.6.1 Simulation Scopes Of Matlab Simulink

Simulation consists of:

a) Modeling DC to DC converter.

b) Modeling fuzzy logic controller.
1.7 Study Restriction

i. This study is restricted and based on student perception.

ii. Accomplish by very tight financial and time limit.

iii. The accuracy of study is on depends on the honesty of respondents while answering the questionnaires form.

1.8 ADDIE Model Of Instructional Design

ADDIE model will use for the development and designing of this DC-DC boost convertors Matlab simulink for enhancing students learning process in power electronic course. ADDIE is an abbreviation for Analysis, Design, Development, Implementation, and Evaluation. This model guides you through the process of creating effective educational courses and materials for your audience. While there are variations of this model in the industry, the concepts are the same. As a professional, this model is more than just an acronym. It is a blue print for success.
The **Analysis** is the most important step in the process. It helps you to determine the basis for all future decisions. A mistake that many beginners make is not conducting a proper analysis at the beginning. It is this analysis that helps you identify your audience, limitations or opportunities, or other important points that will be useful in the design process.

The **Design process** is the brainstorming step. This is where you use the information obtaining in the Analysis phase to create a program or course that meets the needs of your customer or audience. There are many forms of the design process and it can be very tedious at times. Testing your concepts in the design phase will save you time and money.

The **Development phase** focuses on building the outcome of the design phase. This process consumes much of the time spent in creating a sound educational program or course. It includes various steps such as initial drafts, reviews, re-writes, and testing. For larger corporations, this phase can involve numerous individuals to include subject
matter experts (SME), graphic artists, and technical experts. For e-learning courses, this phase could require additional assistance for managing server space and technology.

The Implementation phase includes more processes than simply presenting the materials developed. While the concepts and materials have been tested throughout the process, the implementation phase can uncover topics that require further development or re-design work. The processes for this phase vary based on the size of the organization, the complexity of the program or course, and the distribution of the materials. This includes such concepts as test pilots, train-the-trainer sessions, and other delivery methods to present the materials.

The Evaluation phase plays an important role in the beginning and at the end of the process. Evaluation objectives reflect much of the discoveries found in the Analysis process. These discoveries include the objectives and expectations of the learner. When looking at the process, you must avoid the thought that it is structured in a chronological order.

1.9 Different Learning Styles

Everyone processes and learns new information in different ways. There are three main cognitive learning styles: visual, auditory, and kinesthetic. The common characteristics of each learning style listed below can help you understand how you learn and what methods of learning best fits you. Understanding how you learn can help maximize time you spend studying by incorporating different techniques to custom fit various subjects, concepts, and learning objectives. Each preferred learning style has methods that fit the different ways an individual may learn best.
Auditory Learning Style

Auditory learners would rather listen to things being explained than read about them. Reciting information out loud and having music in the background may be a common study method. Other noises may become a distraction resulting in a need for a relatively quiet place.

Characteristics:
- Retains information through hearing and speaking
- Often prefers to be told how to do things and then summarizes the main points out loud to help with memorization
- Notices different aspects of speaking
- Often has talents in music and may concentrate better with soft music playing in the background
Visual Learning Style

Visual learners learn best by looking at graphics, watching a demonstration, or reading. For them, it's easy to look at charts and graphs, but they may have difficulty focusing while listening to an explanation.

Characteristics:
• Uses visual objects such as graphs, charts, pictures, and seeing information
• Can read body language well and has a good perception of aesthetics
• Able to memorize and recall various information
• Tends to remember things that are written down
• Learns better in lectures by watching them

Kinesthetic or Hands-On Learning Style

Kinesthetic learners process information best through a "hands-on" experience. Actually doing an activity can be the easiest way for them to learn. Sitting still while studying may be difficult, but writing things down makes it easier to understand.

Characteristics:
• Likes to use the hands-on approach to learn new material
• Is generally good in math and science
• Would rather demonstrate how to do something rather than verbally explain it
• Usually prefers group work more than others
CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Simulation refers to the application of computational models to the study and prediction of physical events or the behavior of engineered systems. The development of computer simulation has drawn from a deep pool of scientific, mathematical, computational, and engineering knowledge and methodologies. With the depth of its intellectual development and its wide range of applications, computer based simulation has emerged as a powerful tool, one that promises to revolutionize the way engineering and science are conducted in the twenty-first century.

Simulation-Based Engineering education is defined as the discipline that provides the scientific and mathematical basis for the simulation of engineered systems. Such systems range from microelectronic devices to automobiles, aircraft, and even the infrastructures of oil fields and cities. In a word, Simulation Based Engineering System fuses the knowledge and techniques of the traditional engineering fields like, electrical,
mechanical, civil, chemical, aerospace, nuclear, biomedical, and materials science with
the knowledge and techniques of fields like computer science, mathematics, and the
physical and social sciences. As a result, engineers are better able to predict and
optimize systems affecting almost all aspects of our lives and work, including our
environment, our security and safety, and the products we use and export.

Since fuzzy logic controller can mimic human behavior, many researchers applied fuzzy
logic controller to control voltage output. A thorough literature overview was done on
the usage of fuzzy logic controller as applied DC-DC Boost Converter.

Ismail, N.F.N. Musirin, I. ; Baharom, R. ; Johari, D (2010) proposed a fuzzy logic
controller using voltage output as feedback for significantly improving the dynamic
performance of boost dc-dc converter by using MATLAB Simulink software for the
better understanding of simulation based learning and teaching of power electronic
course. The simulation results are shown that voltage output with fuzzy logic controller
with 0% overshoot shows the better performance compared to the open loop circuit
(without fuzzy logic controller) whereby it has 80% overshoot.

proposed design of a sliding mode controller based on fuzzy logic for a dc-dc boost
converter. Sliding mode controller ensures robustness against all variations and fuzzy
logic helps to reduce chattering phenomenon introduced by sliding controller, thereby
increasing efficiency and reducing error, voltage and current ripples.

The proposed system is simulated using MATLAB/SIMULINK and also create an
effective result on students understanding. This model is tested against variation of input
and reference voltages and found to perform better than conventional sliding mode
controller.

Ahmed Rubaai, Mohamed F. Chouikha (2004) proposed controllers for DC-DC
converters Simulation results have been obtained using appropriate scaling factors
associated with the input variables of the fuzzy controller. Simulation results show the
ease of applying fuzzy control to dc/dc converters, as an interesting alternative to
conventional techniques.
Based on those related work, the researchers make a great efforts to propose the good to overcome the DC-DC Converter problems.

2.2 Simulation-Based Learning

Simulation based engineering experiments is a technique for practice and learning that can be applied to many different disciplines and types of trainees. It is a technique (not a technology) to replace and amplify real experiences with guided ones, often “immersive” in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion. “Immersive” here implies that participants are immersed in a task or setting as if it was the real world.

In the 1980s, during the time when personal computers became less expensive and more simulation software became available, independent groups began to develop simulator systems. Much of this was utilized in the areas of engineering sciences, aviation, military training, medical, nuclear power generation, and space flights.

Simulation-based learning itself is not new. It has been applied widely in the aviation industry (also known as CRM or crew resource management), anesthesiology, as well as in the military and engineering sciences. It helps to mitigate errors and maintain a culture of safety, especially in these industries where there is zero tolerance for any deviation from set standards. (Biggs, 2003).

The simulated environment allows learning and re-learning as often as required to correct mistakes, allowing the trainee to perfect steps and fine-tune skills to optimize technical and industrial outcomes.
Many also believe that simulation-based learning enhances efficiency of the learning process in a controlled and safe environment. The skills requirements which can be enhanced with the use of simulation include:

a. Technical and functional expertise training.
b. Problem-solving and decision-making skills.
c. Interpersonal and communications skills or team-based competencies.

2.3 Pedagogical Philosophy

Power electronics is, by nature, a multi-disciplinary subject, and represents for any instructor a challenging topic to teach. It is an especially demanding course as it requires assimilation of a broad variety of topics, such as circuit analysis, signals and systems analysis, and control theory.

It is widely accepted that hands-on experience in combination with a solid knowledge of theory provides an active learning environment that leads to successful learning in engineering topics.

An effective power electronics simulation is expected to combine theoretical and experimental aspects of the topics by using state-of-the-art software/hardware tools.

2.3.1 Pedagogical Approach

The pedagogical approach by using Kolb learning theory of Experiential Learning Cycle and ADDIE model of instructional design seeks to combine industrial-grade technology
with interactive learning strategies to reinforce the basic concepts of the power electronics course in the context of the innovative power electronics simulation based laboratory. The tools used in the simulation based laboratory are compatible with industrial-grade platforms and encompass both theoretical aspects of power electronics circuits and practical applications. The simulation based laboratory is built upon prior knowledge and background of the students, and is interdisciplinary with respect to the tools and skills required. For example, it combines knowledge in Digital Signal Processor (DSP)/micro-controller hardware/software platforms with power electronics to design and control the power electronic circuits. This signature aspect of the laboratory is intended to create threads among the related subjects to power electronics and retain the students’ knowledge across multiple disciplines for the enhancement of student learning. This pedagogical strategy goes beyond the “divide and conquer” strategy wherein each subject is relegated to its own course and then reduced and analyzed. Engineering education has traditionally followed such a strategy so that upon completion of the course, students find it unnecessary to draw upon the information learned from other courses, with the exception of more advanced courses on the same subject. This has been described as a “filtering” or non-retaining mode of education. (Biggs, 2003).

2.4 Matlab simulation based learning

Matlab (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by Math Works, Matlab allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. The simulation results states that Matlab/Simulink is a suitable platform for control and regulation of the simulation processes, in additional to its dominant role in conducting research tasks.
Although Matlab is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

In 2004, Matlab had around one million users across industry. Matlab users come from various backgrounds of engineering, science, and economics. Matlab is widely used in academic and research institutions as well as industrial enterprises.

Simulink, developed by Math Works, is a data flow graphical programming language tool for modeling, simulating and analyzing multi domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive Matlab or be scripted from it. Simulink is widely used in control theory and digital signal processing for multi domain simulation and Model-Based Design.

2.4.1 Matlab Simulink For Power Electronics

The following section will looks at how the modeling and simulation of a power electronic converter can be carried out using Matlab simulink software.

The blocks which are used to achieve the modeling as follow:

1. Repeating Sequence: this block will be used to generate a number of pulses in terms of time.
2. Sine wave: is used to generate a sinusoidal input with amplitude, frequency and phase.
3. Switch Function (Thy): is used to switch between the sine wave form and the firing pulse which is generated from the repeating sequence.
4. OR Logic: is used to turn the thyristor off when current reaches zero.
2.5 DC-DC Converters

The DC/DC converter is a device for converting the DC voltage to step-up or step-down depending on the load voltage required. If the requirement of voltage is step-up then it is necessary to use a boost converter. If the requirement of voltage is step-down, and then it necessary to use a buck converter. Sometimes, both step-up and step-down is required to cover the load, but at different times then it is necessary to use a buck-boost converter. Therefore, different types of DC-DC converters are used for different voltage levels in load. Generally DC/DC converters are divided into two types.

1- Non isolated DC-DC converter

2- Isolated DC-DC converter

2.5.1 Non Isolated DC-DC Converters

2.5.1.1 Buck converter

Figure 2.1 shows the basic circuit configuration used in the buck converter. There are only four main components namely switching power MOSFET Q1, flywheel diode D1, inductor L and output filter capacitor C1. In this circuit the transistor that is switched ON will put voltage $V_{in}$ on one end of the inductor. This voltage causes the current of the inductor to rise. When the transistor is switched OFF, the current continue to flow through the inductor. At the same time, it flows through the diode. Initially it is assumed that the current flowing through the inductor does not reach zero; thus the voltage will only go across the conducting diode during the full OFF time. The average voltage depends on the average ON time of the transistor on the condition that the current of the inductor is continuous.
2.5.1.2 Boost Converter

A boost converter or a step up converter is a non-isolated converter. It is the most commonly used DC/DC converter, especially used in UPS and PV. This is because battery charge requires high DC voltage to be fully charged. Figure 2.2 shows the basic boost converter. The theory of a boost converter is not complicated as other converters rather. It is simple and straightforward. If the switch, S is ON, the current flows only through the inductor, which has stored energy. When the switch, S is OFF, the energy in the conductor is translated to a capacitor, which usually has a large capacity to store a bigger amount of energy. Finally, this energy converts to load with a high DC voltage.

Figure 2.1: The Basic Circuit Configuration of the Buck Converter

Figure 2.2: Basic Circuit of Boost Converter
2.5.1.3 Buck-Boost Converter

The main components in a buck-boost converter are the same as in the buck and boost converter types, but they are configured in a different way. Figure 2.3 in buck-boost converter, a step-up or step-down voltage can change the value of duty cycle. Nevertheless, in a similar process, once the switch is ON, the inductor begins charging and, the converter is stored with energy. However, once the switch is OFF, the circuit changes into inductor and capacitor simultaneously hence all the stored energy in the inductor is converted to capacitor. One thing that controls the voltage is the duty cycle. If the duty cycle is big, voltage is high in the load. On the other hand, when the duty cycle is small, voltage in the load is low.

![Figure 2.3: Basic Circuit of Buck-Boost Converter](image)

2.5.1.4 Cuk Converter

All the three converters buck, boost and buck-boost converters, transfer energy between input and outputs through the inductor. The analysis is based on voltage balance across the inductor. The Cuk converter in Figure 2.4 uses capacitive energy transfer. This analysis is based on current balance of the capacitor.
However, the buck-boost converter such as the Cuk converter can step the voltage up or down, depending on duty cycle. The main difference between the two buck-boost and Cuk converters is that, the series of inductors at both input and output record much lower current ripple in both circuits.

### 2.5.2 Isolated DC-DC Converters

#### 2.5.2.1 Fly Back Converter

Actually the fly back converter shown in Figure 2.5 can be recognized as an extension of buck-boost converter. The buck-boost converter is shown Figure 2.3. If it changes the inductor to a transformer, then it becomes a fly-back converter. This is because the direction of diode ON the secondary side of Fly-back converter works in both directions.

Generally, the input to the circuit is unregulated DC voltage that is obtained by rectifying the utility AC voltage followed by a simple capacitor filter. The circuit can offer single or multiple isolated output voltages and can operate over a wide range of input voltage variation. In terms of energy-efficiency, fly-back power supplies are lower
than many other circuits but it’s simple topology and low cost makes it popular in low output power range.

Figure 2.5: Basic Circuit of Fly-Back Converter

2.5.2.2 Forward converter

In the Fly-back converter, there are two separate phases or energy storage and delivery to the output. As the forward converter shown in Figure 2.6, it uses the transformer in a more traditional style whereby it transfers energy directly between input and output in just one step. However, the forward converter reverses the polarity of magnetic flux in the core of a transformer core for each alternate half-cycle. Hence, there are fewer tendencies to cause saturation compared to the Fly-back converter. This means the transformer can be significantly smaller, for the same power level. This together with the
tighter and more predictable relationship between input and output voltage makes the forward converter an attractive choice for high power applications.

Figure 2.6: Basic Circuit of Forward Converter

2.5.2.3 Functions of DC-DC converters

The DC-DC converter has some functions. These are:

i. Convert a DC input voltage $V_s$ into a DC output voltage $V_o$.

ii. Regulate the DC output voltage against load and line variations.

iii. Reduce the AC voltage ripple on the DC output voltage below the required level.
5.5.2 Recommendations for Further Research Study

i. Recommendations for the production of Matlab simulink for other power electronics topics and experimental.

ii. Include the rules of fuzzy logic. When more the rules of fuzzy logic, the output of fuzzy logic would more precise. For this project has used 25 rules so for future works, 49 rules could be adopted.

iii. Contrast with conventional controller such as PI controller with fuzzy logic controller to study the characteristic both of controllers. Then make the comparison which the better controller.
REFERENCES


