MARX TOPOLOGY DC-DC BUCK CONVERTER FOR HIGH VOLTAGE GAIN ACHIEVEMENT

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To my beloved parents, ASHA and ABDIRAHMAN, my little brother, AFI and beloved uncle Eido, the other family and brothers, thank you

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ABSTRACT

This study present Marx topology DC-DC buck converter (MBC) with a series connection at the input side and parallel connection at the output side. With these circuit configurations the high voltage gain can be achieved. In Marx topology buck mode, stages capacitor was charged in series and discharge in parallel to achieve the step-down buck characteristic. Due to the number of stages n, the buck ratio can be achieved by changing the duty cycle D, the number of circuit stages n or both. A two-stage MBC with a duty cycle of 19.4% between the input and output voltages were designed and simulated for 400 V and 48 V. Further test with duty cycle of 15.1% where the input and output are 400 V and 36 V, and duty cycle of 23.1% where the input and output are 400 V and 60 V. Simulation of output power of 1 kW, 2.5 kW and 5 kW were conducted to check the relation of the circuit towards the efficiency, output voltage and duty ratio. Simulation of switching frequency at 25 kHz, 50 kHz and 75 kHz to check the relation towards circuit parameters design. Simulation with duty cycles of 15.1%, 19.4% and 23.1% were conducted to check the relationship for the output voltage. The MBC circuit can perform the buck operation by varying the duty cycle and the number of stages for the desired output voltage. Therefore, the design of the proposed converter was confirmed. The maximum efficiency of MBC is 95% was obtained from the simulation result.

ABSTRAK

Kajian ini mempersembahkan topologi Marx DC-DC buck converter (MBC) dengan sambungan bersiri di bahagian input dan sambungan selari di bahagian output. Dengan konfigurasi litar ini keuntungan voltan tinggi boleh dicapai. Dalam mod buck topologi Marx, kapasitor peringkat telah dicas secara bersiri dan nyahcas secara selari untuk mencapai ciri buck step-down. Oleh kerana bilangan peringkat n, nisbah wang boleh dicapai dengan menukar kitaran tugas D, bilangan peringkat litar n atau kedua-duanya. MBC dua peringkat dengan kitaran tugas 19.4% antara voltan input dan output telah direka bentuk dan disimulasikan untuk 400 V dan 48 V. Ujian selanjutnya dengan kitaran tugas 15.1% di mana input dan output adalah 400 V dan 36 V, dan kitaran tugas sebanyak 23.1% di mana input dan output adalah 400 V dan 60 V. Simulasi kuasa output 1 kW, 2.5 kW dan 5 kW telah dijalankan untuk menyemak hubungan litar terhadap kecekapan, voltan keluaran dan nisbah kewajipan. Simulasi frekuensi pensuisan pada 25 kHz, 50 kHz dan 75 kHz untuk menyemak perkaitan dengan reka bentuk parameter litar. Simulasi dengan kitaran tugas sebanyak 15.1%, 19.4% dan 23.1% telah dijalankan untuk menyemak hubungan bagi voltan keluaran. Litar MBC boleh melakukan operasi buck dengan mengubah kitaran tugas dan bilangan peringkat untuk voltan keluaran yang dikehendaki. Oleh itu, reka bentuk penukar yang dicadangkan telah disahkan. Kecekapan maksimum MBC ialah 95% diperoleh daripada hasil simulasi.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternative current
DC	-	Direct current
MBC	-	Marx Buck Converter
HVAC	-	High Voltage Alternating Current
ICT	-	Information Communication Technology
IT	-	Information Technology
VM's	-	Virtual Machine
PSiP	-	Power Supply in a Package
PSoT	-	Power Supply in a Telecom
EMI	-	Electromagnetic Interface
Sic	-	Silicon carbide
DC-DC	-	Direct Current to Direct Current
IGBTs	-	Insulated-gate bipolar transistor
SLAs	-	Service Level Agreements
PLECS	-	Piecewise Linear Electrical Circuit Simulation
kHz	-	Kilohertz
LED	-	Light-emitting diode
RAID	-	Redundant array of independent disks
SICS	-	Swedish Institute of Computer Science
PDUs	-	Power distribution units
η	-	Efficiency
Fsw	-	Switching frequency
CCM	-	Continuous-conduction-mode
DCM	-	Discontinuous-conduction-mode
NEMPs	-	Nuclear electromagnetic pulses
HEMPs	-	High-altitude electromagnetic pulses
Ω	-	Ohm

μF	-	microfarad

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

This chapter presents the detail information related to project research which consists of background of the study, problem statement, objectives, and scope of studies. This project is DC-DC converter for Marx buck converter, which converts uncontrolled DC input to a controlled DC output with a desired voltage level. The input voltage was be stepped down by the buck of 400 V to output voltage 36 V, 48 V, 60 V with the switching frequency of 25 kHz, 50 kHz, 75 kHz. DC voltage can produce a certain amount of constant electricity, which becomes weak when it travels further longer [1]. DC-DC converter is to increase or decrease supply voltage based on the required performance. Buck converter is a type of switching-mode power supply which is used for stepping-down.

DC voltage level converters can be offered as a method to generate multiple voltage levels from a single DC supply voltage to feed of sub-circuits in the device. This method of generating multiple voltage levels from a single telecom supply source can reduce the device area substantially. The most common topologies available will be analysed to understand each system. The three most common topologies are buck (step down), boost (step up) and buck-boost (step down/step up). Buck Converter the output voltage must always be lower than the input voltage. A simple buck converter circuit consisting of a MOSFET, diode, inductor, capacitor and a load. While the MOSFET is turn on, current is flowing through the load via the inductor. The action of any inductor opposes changes in current flow and also acts as a store of energy [2]. In this case, the MOSFET output is prevented from increasing immediately to it is peak value as the inductor stores energy taken from the increasing output. The DC-DC converter can be use in healthcare like dental imaging laboratory and medical, also communications, computing, and business system in an electric motors drives. DC-DC converters are used 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 it is own voltage level requirement different from the supplied voltage by the telecom supply or an external supply [3]. Additionally, the telecom supply voltage declines as it is stored energy is drained. Switched DC-DC converters offer a method to increase voltage from a partially lowasd telecom supply voltage, thereby saving space instead of using multiple batteries to accomplish the same thing. Most DC-DC converter circuits also regulate the output voltage.

Some exceptions include high-efficiency LED power sources, which are a kind of DC-DC converter that regulates the current through the LEDs, and simple charge pumps which is doubles or triples the output voltage [4]. Data Center (DC) has many definitions; all of them try to describe the functions and components of a DC. Cisco describes a DC as: a physical facility that organizations use to house their critical applications and data. A data canter's design is based on a network of computing and storage resources that enable the delivery of shared applications and data. The key components of a data center design include routers, switches, firewalls, storage systems, servers, and application-delivery controllers. According to data center are computer warehouses that store large amounts of data that meet the daily transaction processing needs of different businesses. They contain servers for the collection of data and network infrastructure for the utilization and storage of the data.

Data centers include redundant critical power and cooling components to provide select maintenance opportunities and an increased margin of safety against IT process disruptions that would result from site infrastructure equipment failures. The redundant components include power and cooling equipment [5]. DC-DC systems that employ transformers or inductors operate at substantially higher frequencies, necessitating the use of much smaller, lighter, and less expensive wrapped components. As a result, these strategies are used even when a mains transformer is available. as an example, it is better to rectify voltage DC in residential electrical appliances, which is converted using switch-mode procedures. At the necessary voltage, high-frequency AC frequently rectifies to DC. The complex circuit as a whole is less expensive and more efficient than a simple mains transformer circuit with the same output [6]. In the context of varying voltage levels, DC-DC converters are commonly utilised for DC microgrid applications. DC power supply is used in most of the appliances where a constant voltage is required. An AC voltage from the generator can be change their strength when they travel through a transformer. An Alternating Current (AC) power supply is one in which the voltage varies instantly with the flow of time [7].

The charge carriers in an AC supply change their direction on a regular basis, and AC supply is employed as a utility current for home uses. A circuit consisting of an inductor, a Mosfet, and a load converts this utility AC current to DC. A DC voltage can also be stepped up or down to the appropriate voltage using such a circuit. A buck converter is a converter with a lower output voltage than the input voltage. The cascade connection of two basic converters, the step-down converter and the buck converter, produces a buck converter. These two converters can be combined into the single buck input provides energy to the inductor and the diode is operating [8].When the switch is open the energy stored in the inductor is transferred to the output, no energy is supplied by the input during this interval.

This power source energy storage devices such as batteries or fuel cells, generators, or other power supplies may derive from the electric power grid. The Marx Buck DC-DC converter steps down a 400 V DC voltage source to 36 V, 48 V, and 60 V DC output voltages. The switching frequency is set to 25 kHz, 50 kHz, or 75 kHz. Components such as MOSFETs, inductors, capacitors, and resistors are chosen based on the maximum current and voltage that they can withstand according to their specifications [9]. When designing power switches such as MOSFETs, the designer must consider the maximum current and voltage stress that the MOSFET and diode can handle under on and off conditions. Furthermore, to avoid component failure, the maximum current that the inductor can support is the value of its operating frequency [10].

1.2 Problem Statement

Nowadays, data center is an essential part of servers, racks, network connectivity, infrastructure security, storage, business, and industrial world. And facing many challenges like, real time monitoring, reporting capacity, planning managing power, performance maintenance, high energy efficiency, size and cost. So, data center the main issue can mention the size, high efficiency and power losses can operate in High Input Voltage Direct Current. electronic devices that can be used to efficiently convert direct current from one voltage to another. The operation of the Data center is switching equipment provides a unique nonlinear function for DC-DC converters, including the so-called Telecom supply [5]. As mentioned above the problem of data center is efficiency and size, the solution is to be proposed less size and efficient power to generate for Marx Buck Converter (MBC), the main objective of the thesis is to look into the controller design for maximizing stage size of MBC, enhancing efficiency and reliability of efficiency and power so the result to solve the problem statement and revert to the objective.

1.3 Objectives

The objectives of this project are:

i. To design DC-DC Buck Converter for high voltage gain achievement using Marx topology technique approach.

ii. To analyse current and voltage parameters response during high voltage gain operation.

1.4 Scope of Study

The scopes of the research are:

i. The input voltage range is from 400 V

ii. The output voltage range is 36 V, 48 V, 60 V

iii. The switching frequency is set to 25 kHz, 50 kHz, 75 kHz

iv. The power generates is set to 1 kW, 2.5 kW, 5 kW.

v. The power generates is set to 200 W

1.5 Thesis Outline

This project focuses on designing Buck DC-DC converter with high voltage gain by using plecs program/Simulink software.

To analyse current and voltage parameters response during high voltage gain operation by classifying and comparing to analyse the DC-DC Buck converters in term of system performance. Conventional Buck Converter with voltage will increase efficiency and performance, where as to reduce power efficiency of semiconductors. This is study of Buck converter for Marx topology and high voltage gain achievement. The input voltage range is from 400 Vin the output voltage range is 36 V, 48 V, 60 V the switching frequency is set to 25 kHz, 50 kHz, 75 kHz.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Firstly, this chapter discuss several types of Marx topology DC-DC converter and Data Center, High voltage gain such as Design of Conventional Buck DC-DC converter, Classification of DC-DC etc. Secondly, a review on parties of DC-DC conversion in terms of previous researcher work related to the Data Center, DC-DC buck converter, and high voltage gain achievement topics. In addition, some other related the characteristics of the last of power distribution system and set-up of Marx topology is all about gap from the previous study for related this work. This chapter will discuss.

2.2 Application of DC - DC converter

DC-DC converter decreasing the In the regenerative braking of the DC motor the DC converter can be used to return energy baked into the supply. This feature results in energy saving for a frequent stop transportation system and is used in DC voltage regulation in many applications from low-power applications to high-power applications. DC conversion is necessary, the key to every system is to achieve productivity to satisfy device requirements. In this field, different topologies have been created, even both topologies can be considered part of a combination for buck converter topologies. For low power levels, linear regulators can provide a high-quality output voltage. Switch regulators are utilized for higher energy levels. Electronic semiconductor switches are used by switch regulators to transform situations on or off [11]. Additional switching regulators can achieve high energy conversion efficiency because their small power losses during on and off state of switch compared to linear. DC-DC converter is useful in combining different power sources whose capacity and voltage levels vary for a well-regulated output voltage. DC-DC converters are well developed for low and medium power applications. One of the most recently growing applications is DC distribution systems at 400 V such systems have been gaining more and more popularity for telecom, data centers and commercial buildings due to it is various benefits [12]. It offers better efficiency and higher.

2.2.1 Function of DC-DC converter

The DC-DC converter can perform a variety of tasks. These are the following:

i. Create a DC output voltage Vo from a DC input voltage Vin.
ii. Adjust the DC output voltage to compensate for fluctuations in the load.
iii. Lower the DC output voltage's AC voltage ripple.
iv. Create a barrier between the source of the input and the load (if required).
v. Avoid electromagnetism in the provided system and the input source.[13].

2.2.2 Advantage and dis-advantage of DC-DC converter

i. It simplifies the power supply systems in the circuit.
ii. It provides isolation in the primary and secondary circuits from each other.
iii. It provides a technique to extend potential (voltage) as required.
iv. It is available as a hybrid circuit with all elements in a single chip.
v. It is also used in the regulation and control of DC voltage.
vi. The output is well organized as positive or negative.
vii. Telecom supply space can be reduced by using a converter.

Disadvantages of DC-DC converter.

i. Switching converters are more complicated, have a noise problem, and are more expensive, although this has been addressed with better chip design.
ii. DC-DC converters are classified into a variety of types depending on the application. One classification is based on the isolation between input and output circuits, and the other is based on the lack of isolation between input and output circuits. Also dependent on power transfer, i.e., energy flowing

from the supply side through the magnetic field to the output at the same time or energy saved in the magnetic field to be released adjacent to the load [14].

2.3 High voltage DC-DC converter

DC-DC converter decreasing the switching losses along with reducing the voltage and current stresses of the circuit components. High voltage gain DC-DC converter with single-input multi-output is introduced. This topology can operate step-down converter, but it has dis-advantages of high complexity and big size. In recent years the multi-input multi-output converters are gaining popularity due to their ability to combine several input voltage sources and produce several voltage levels at their output terminals [15]. There are various methods to design multi-input multi-output converters. This converter requires as many switches as it is input–output terminals, which increases the complexity of the converter. For more input sources and output loads the power sharing between the connected loads reduces.

In many industrial applications it is required to convert a fixed-voltage DC source into a variable-voltage DC source. DC-DC converter converts directly from source and is simply known as a DC converter. DC converter can be considered as DC equivalent to an AC transformer with continuously variable turns ratio. Like transformer, it can be used to step down or step up a DC voltage source [16]. DC converters widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. The DC converters provide smooth acceleration control, high efficiency, and fast dynamic response. DC converter can be used in regenerative braking of DC motor to return energy bake into the supply and this feature results in energy saving for transportation system with frequent stop and also are used in DC voltage regulation. There are many types of DC-DC convertor which is buck (step down) converter, boost (step-up) converter, buck-boost (step up/step-down) convertor [17].

DC conversion is a great importance in many applications starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs and requirements. Several topologies have been developed in this area but all these topologies can be considered as apart or a combination for the basic topologies. Switching regulators use power electronic semiconductor switches in On and Off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high efficiency energy conversion. Moreover, the number of switches and input sources significantly increases the number of outputs [17].

This leads to higher power loss, bigger size, higher weight and complexity of this category of converters. Furthermore, the voltage polarity of the out terminal is different from that input voltage source. However, active and passive switches need to bear a higher voltage stress and, therefore this is a major drawback of this topology. High voltage gain without using extreme duty cycles or transformers, which allow high switching frequency and Low voltage stress in switching devices, along with modular structures and More output levels can be added without modifying the main circuit, which is highly desirable in some applications such as renewable energy systems. DC-DC converters are widely used in industrial applications and computer hardware circuits. DC-DC converter is a switching circuit which transforms the voltage of the DC source (VI) into other desired voltage in the load side (Vo) [18].

This is achieved by the circuit's appropriate switching operation. DC-DC converters are commonly used in regulated switching-mode, DC power supplies and DC motor drives are buck converter or step-down switch mode power supply can also be called a switch mode regulator. Buck converter produces a lower average output voltage than the DC input voltage, V. Figure 2.1 Block diagram of DC-DC regulator when the switch S is on, the diode D is operated and the load and the inductor both receive energy from the input. The inductor current flows through the diode D when the switch is off, transferring some of the stored energy to the load R [19].

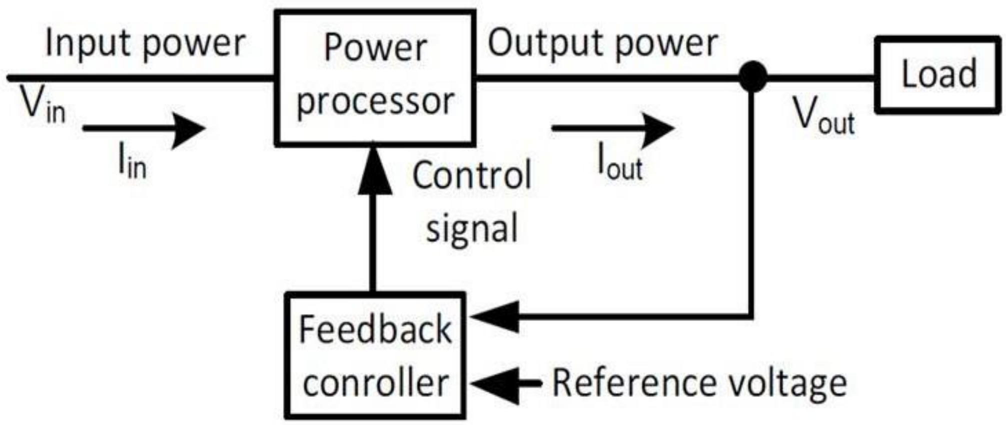

Figure 2.1: DC-DC regulator [19]

2.4 DC-DC converter issues for data center

A data center is a dedicated facility where computing systems and networking, data storage and other associated equipment are physically located in maintaining and operating. In the early days of computing most computer hardware had to reside in a data center like environment, as the power and cooling requirements was quite different from the ones of today's personal computers. In this section, the services provided by data centers are introduced and basic data center infrastructure is examined. The purpose of a data center is naturally to provide services to the entity operating. The data center itself or to external clients' services provided by data centers. currently might be roughly divided in the following categories [20].

i. Data storage
ii. Data processing
iii. Data transmission

A data centre is a platform that houses a computer network's important systems, Limited power backup, HVAC, security, servers, databases, content, applications storage, and networking equipment are only some of the items that used in data center. All of an organization's resources for processing data, assembling and preserving data, storing and transferring digital information, as well as offering applications and services such as web hosting, intranet, telecommunications, and technological expertise, are housed in data center. A data centre requires optimal power availability to keep IT services running at all hours of the day. It uses more energy than a typical office building and is comparable to large manufacturing businesses. To attain high

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