Ain Shams University
Faculty of Engineering

Investigation of DC Chopper Using Power Transistors

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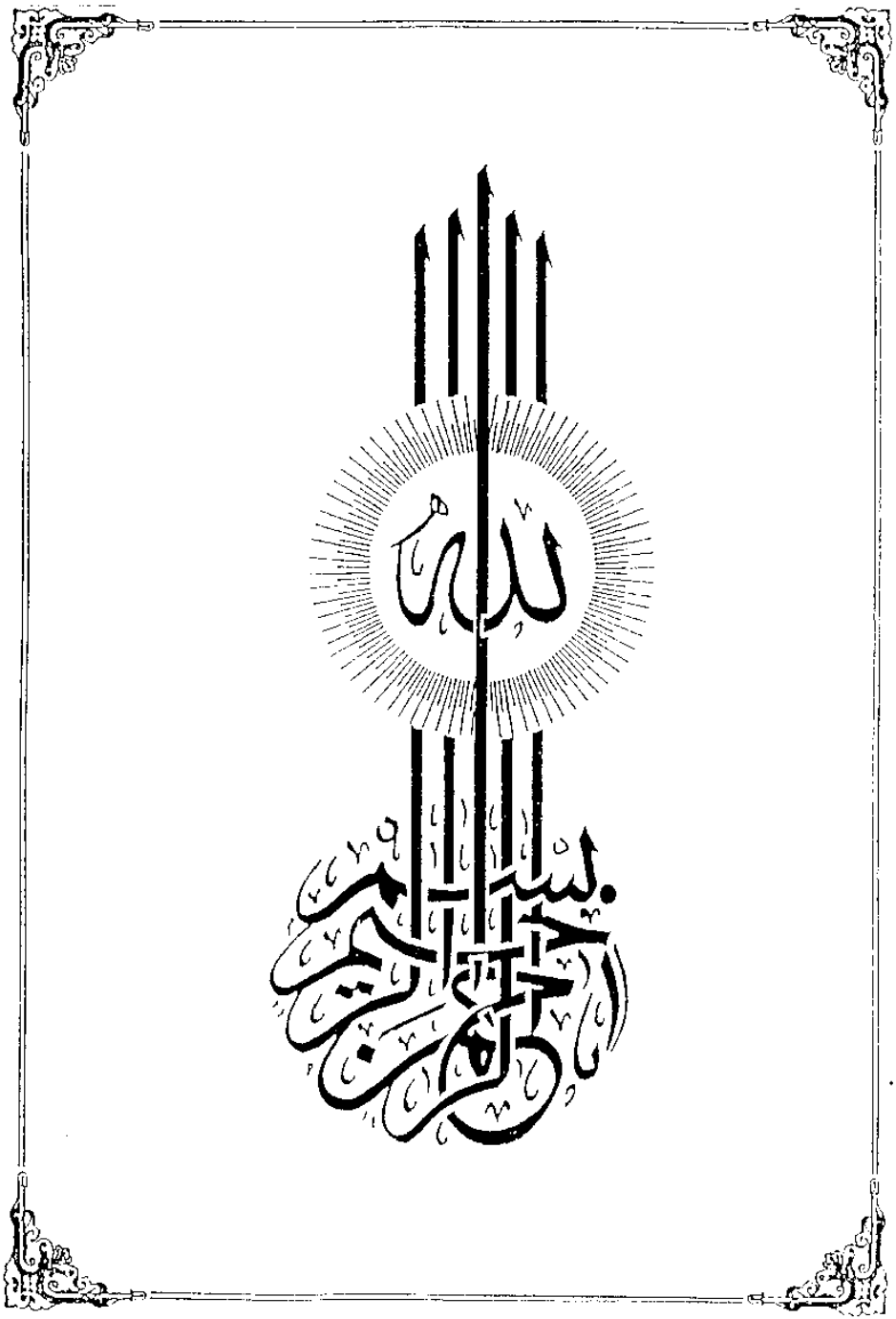

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering .

The work included in this thesis was carried out by the author in the department of Electrical Power and Machines , Ain Shams University ,from October 1986 to February 1992.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution .

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SUMMARY

In recent years , variable DC voltage applications are found in a wide range of industrial processes . Many configurations and techniques are used to obtain such a voltage . Among these techniques , the DC choppers have the advavtages of simplicity , higher effeciency , and lower cost .

For years thyristorized DC choppers have been used with all the commutation problems . Recently , the new trend is towards the transistorized chopper .

Transistorized choppers have the advantages of control simplicity , fast switching times , absence of commutation , and smaller switching losses ; specially in high frequency applications . On the other hand , the transistor requires a special scheme of active protection . In this context , a one quadrant DC chopper with a novel scheme of over load and short circuit protection has been designed and built in the laboratory .

Tests have been performed experimentally and verified analytically for different types of loads , including both passive and dynamic loads .

The chopper robustness has been tested and satisfactry operation was observed . Also , the associated protection scheme has been tested under severe over load and showed fast and reliable response .

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CHAPTER (1)

INTRODUCTION

1.1 General

Control systems using electronic devices are used in a wide range of applications in recent years and have played a vital role in the advancement of engineering and science .
In addition to its extreme importance in missile guidance and aircraft systems , it has become an important and integral part of modern manufacturing and industrial processes [1] .

Among this wide range of applications , variable speed drives have an established position in the field of control systems .

For a long time , direct current motors have been used in the field of variable speed drives . The versatile control characteristics of DC motors have contributed to their extensive use in industry .
Direct current motors can provide high starting torques which are required in some applications such as traction drives . Control over a large speed range can be easily achieved . The methods of control are simple and less expensive than those of alternating current motors .

Although commutators prohibits their use in certain applications , such as high speed drives and operation in hazardous atmospheres , DC motors play a significant role in many industrial drives [2] .

Speed of DC motors can be controlled through the variation of

flux, armature resistance, and the armature voltage . At present , separately excited DC motor controlled by converter is the most widely used drive in industry . Such system provides speed control over a wide range and constitutes a major part of power electronics field [3].

The variable DC voltage required to motor control is mainly obtained from a fixed supply voltage (AC or DC) by phase control or chopper control . This is illustrated in figure (1-1) . In both methods , the motor will respond to the average value of the voltage waveform .

In phase control scheme , the conversion from AC -to- DC is achieved by rectification using semi or full converters . Semi-converters are preferred to be used . However , full converters must be used when reversibility or regenerative braking are required . This system is simple , inexpensive , and the DC voltage can be controlled smoothly over a wide range . However , the power factor at the input AC supply decreases at lower output DC voltages.

If the supply is DC , chopper circuits are used . For years , thyristors have been used in chopper circuits and auxiliary circuits are required to turn off the thyristors . This makes the chopper control relatively complex .

Recently , power transistors of high voltage , high current are available . Therefore , the forced commutation problems of thyristors are avoided which simplifies the control of chopper circuits . Also , there is a new version of thyristors , referred

to as gate turn off thyristor (GTO) . This type is highly recommended for chopper circuits .

The difference between transistorized and thyristorized chopper circuits is that the former operates at relatively high frequency which reduces the ripple in motor current .

The advantage of chopper circuits is the simplicity of controlling the average voltage which can be controlled by varying the conducting time (t_{ON}) of the switching element , see figure (1-1) .

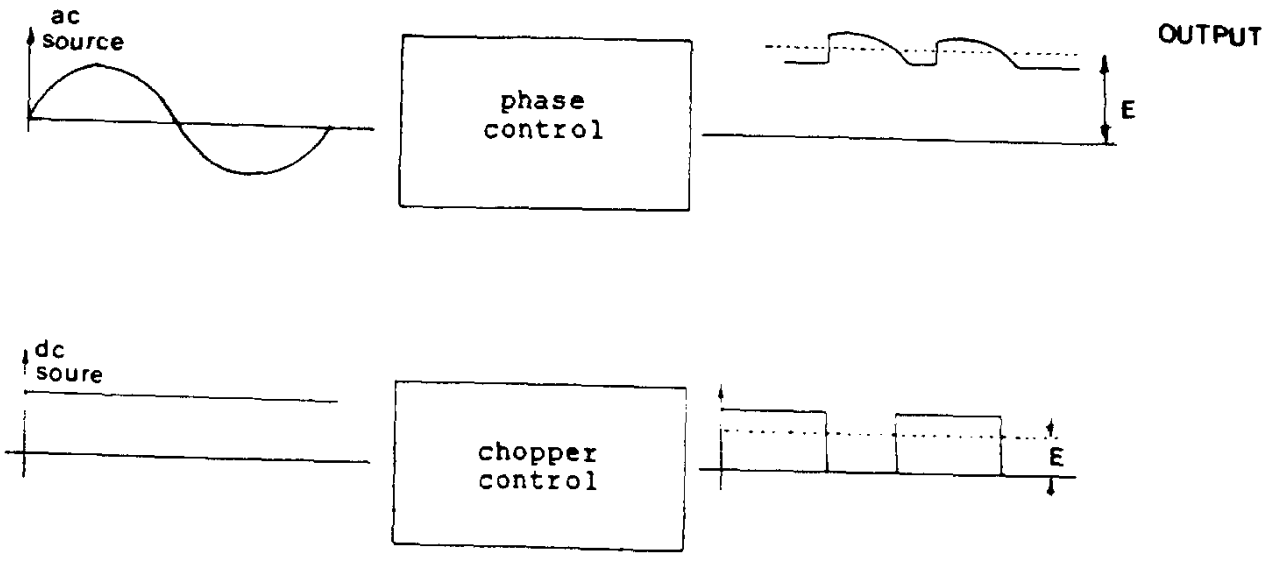


Figure (1-1)

1.2 Thesis Objectives

The main objectives of this thesis are

(1) To be acquainted with the power transistor as a switching element , circuit requirements for satisfactory operation , and its protection .

(2) Using the transistor in a chopper circuit for the purpose of obtaining a speed control of a separately excited DC motor .

(3) Design and construction of the required base drive and protection circuits .

(4) To build the proposed system setup in the laboratory .

(5) To simulate the chopper operation and then compare the analytical and the experimental results .

1.3 Thesis Layout

The presented thesis contains five chapters in addition to a list of references and appendices .The layout of the five chapters is as follows ;

Chapter (1) : Gives a general introduction about the recent control techniques for DC motors . It also gives the thesis objectives and layout

Chapter (2) : Includes the chopper circuit , its analysis , and control circuit .

Chapter (3) : Deals with the protection circuit . In this chapter , a novel short circuit and over load scheme of protection circuit and its performance characteristics is presented .

Chapter (4) : Gives experimental and analytical results . A comparison is held between the two kinds of results .

Chapter (5) : Contains the conclusions and recommendations

CHAPTER (2)

THE CHOPPER CIRCUIT

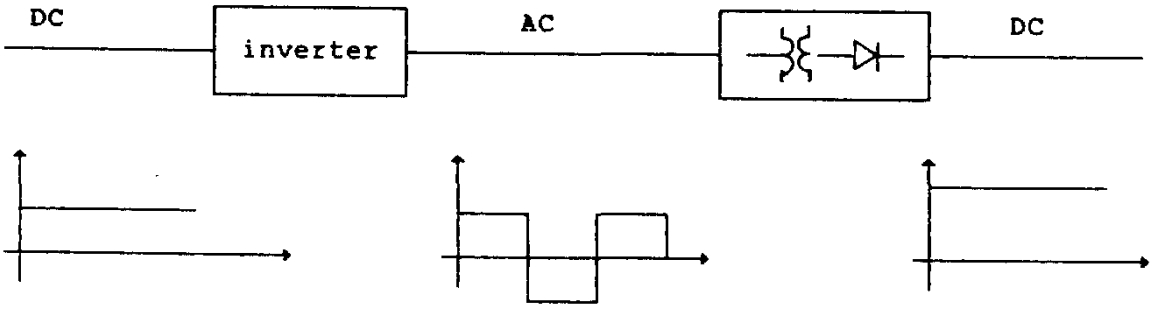
2.1 Introduction

Many industrial drives and processes require a variable DC voltage source . Among of these are the battery chargers , subway cars , battery operated vehicles , and variable speed drives. Classically , a variable DC voltage is obtained from a fixed DC voltage by two methods ; a resistance controller or motor generator set . The resistance controller method is associated with a heavy power loss . In the second method of motor generator set , three machines of the same ratings are involved and therefore the system is bulky , costly , slow in response , and less efficient .

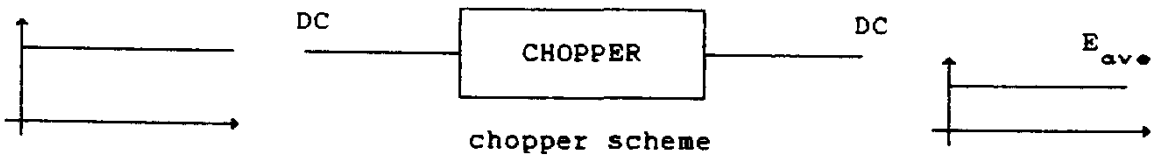
In the past thirty years , and due to the availability of high power solid state devices , solid state power converters have become practical and economically viable for drives powered from DC sources . These converters offer great efficiency , faster response , smooth operation , minimal maintenance , smaller size , and lower weight and cost [2] . There are two broad types of DC to DC converters namely , inverter - rectifier circuit and DC choppers . The block diagram of these two types is shown in figure (2-1) . In rectifier - inverter scheme , the DC is first converted to AC , which may stepped up or down by a transformer and then rectified back to DC . The conversion is in two stages , which led the system to be bulky , costly , and of lower efficiency . however , the transformer provides isolation between load and

source .

In DC choppers , conversion from DC to DC is obtained directly and therefore the system is simple , cheap , and of high efficiency . This technique is relatively new . The chopper can replace the resistor used in series with the armature to control the speed of a DC motor . Therefore , it can be used in battery operated vehicles where energy saving is of a prime consideration. Choppers can also provide regenerative braking of motors. Therefore , choppers find wide applications in traction systems . Choppers are used in other applications such as fork lifts , marine hoists and mine - haulers . Some of the good features of the chopper drives are ; smooth control , high efficiency , fast response , and regeneration braking .



inverter - rectifier scheme



chopper scheme

figure (2-1)

DC - to - DC converters

2.2 DC Choppers (General)

2.2.1 Principle of operation

A chopper is a solid state ON - OFF switch that connects the load to and disconnects it from the supply producing a chopped load voltage from a constant input supply voltage . This process is illustrated in figure (2-2) .

During the period t_{ON} , when the chopper is ON , the supply terminals are connected to the load terminals , and during the interval t_{OFF} , the load current flows through the freewheeling diode and the load terminals are shorted as long as the load current does not fall to zero . A chopped voltage is thus produced at the load terminals .

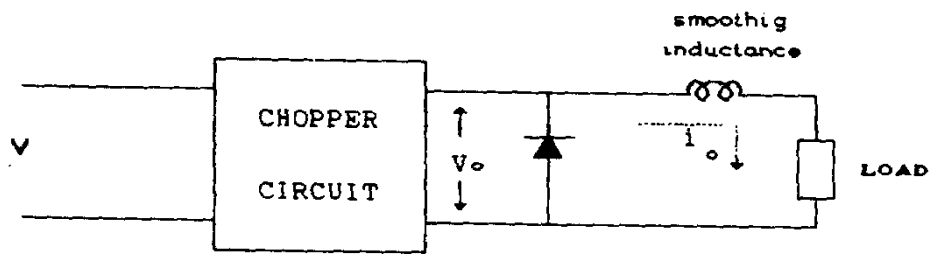


Figure (2-2-a)

The chopper circuit and its load

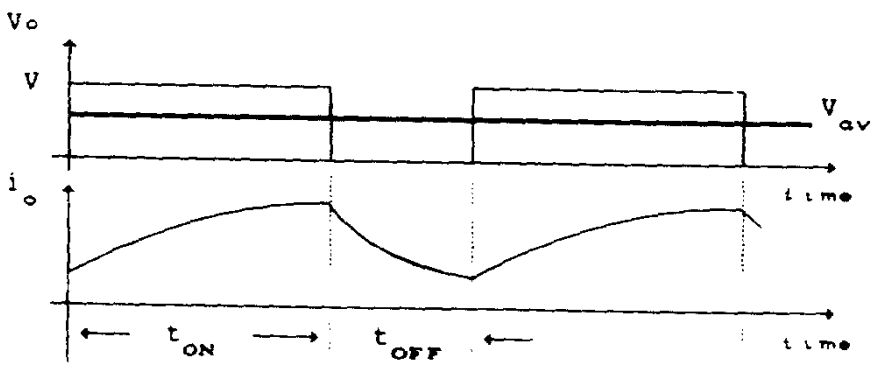


Figure (2-2-b)

Output voltage and load current for continuous current mode