Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit: 43 Further Electrical Machines and Drives

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Electronic Converters Used in Electric drives:

Table of Contents

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structure.

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

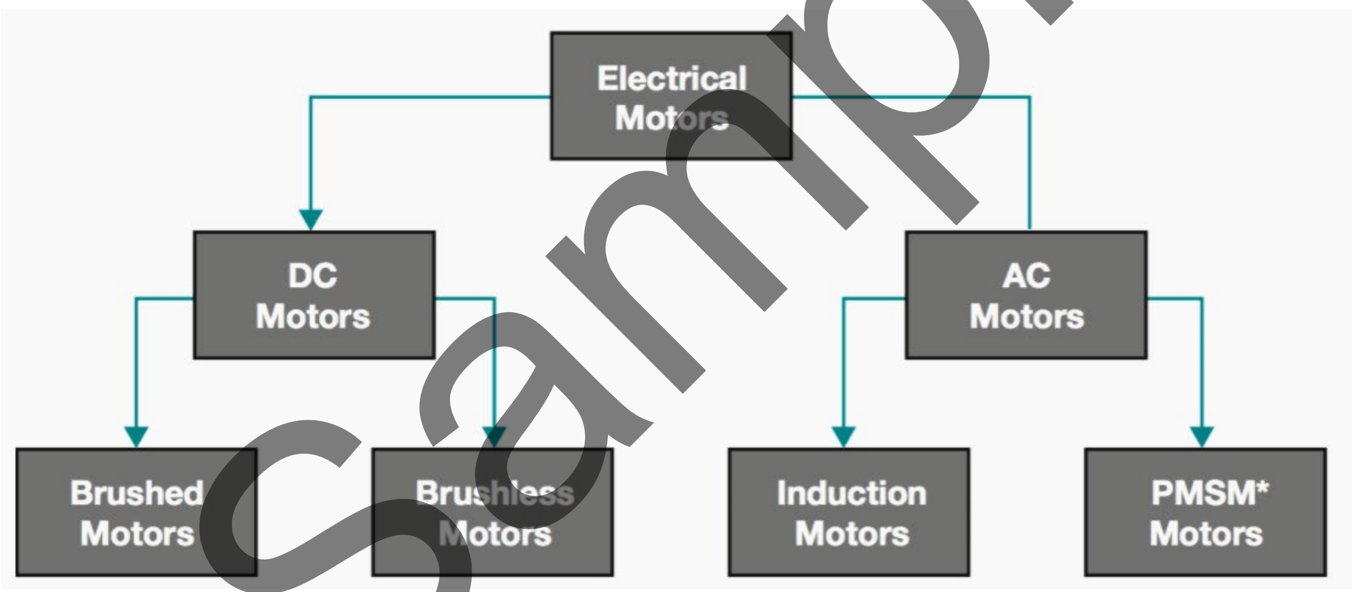
INTRODUCTION

Concepts of Electric Drives and their Classifications.

In this section we will examine how electrical drives may be classified.

Power supplies can be classified into two broad categories: AC power supplies and DC power supplies. As we know, mains power is generated in the form of AC power and since it is more economical, we use AC for transmission. Consequently, most of the electrical machines/devices operate from AC power. However, the standard Voltage and Frequency supplied from the generating stations might not be good enough to drive certain Industrial machines. In such cases, we employ converters and inverters to convert one form of power supply into another form having a different voltage rating, current rating, or frequency rating.

As we have seen from workbook one, electrical drives are available in a wide range of design types to serve a wide number of applications. In general, these drives come under the general heading of AC and DC machines, and these can be classified further, as shown below:



Motor Type	Voltage Levels	Power Levels	Applications	Advantages	Disadvantages
Brushed DC	<100V	<100W	Toys, coffee machine, gate openers, etc.	Easy to spin, low cost	Brushes wear out, Inefficient
Brushless DC	<600V	Up to a few kW	Household appliances, white goods, pumps	Long life/reliable, high efficiency	Cost, complicated control
AC induction	>600V	>750 W	Industrial and factory automation	Low cost, less maintenance, rugged, reliable in wide power range	Starting issues, low-power factor correction, complicated speed control

Table 1. Comparison of motor types.

Table 1. highlights the applications for AC (induction) and DC (brushed and brushless) motors, their range in terms of voltage and power levels, and their advantages and disadvantages.

The drive configuration for these motors is generally the same; however, what differs is the power converter topology in the power converter circuit, which we will now examine**.**

What do we mean by power convertor topology? [1]

Power convertors comprise a network of electrical components that link, adapt, and transform an input power source into a specific output which can be considered as a source generator and an output load respectively.

Each type of network will comprise a range of linear and non- linear electronic components designed and constructed to deliver the necessary power output having the electrical characteristics required by the specific type of electric drive[2].

The design of a specific power convertor for an electric drive will need to consider the most appropriate convertor architecture and that which will most likely possess the characteristics and power output required. We refer to these different and collective forms of power convertor types as topologies, more specifically switching topologies. We will examine these later.

Considering first the function and arrangement of a typical power convertor for a motor drive we can refer to the block diagram and description below:

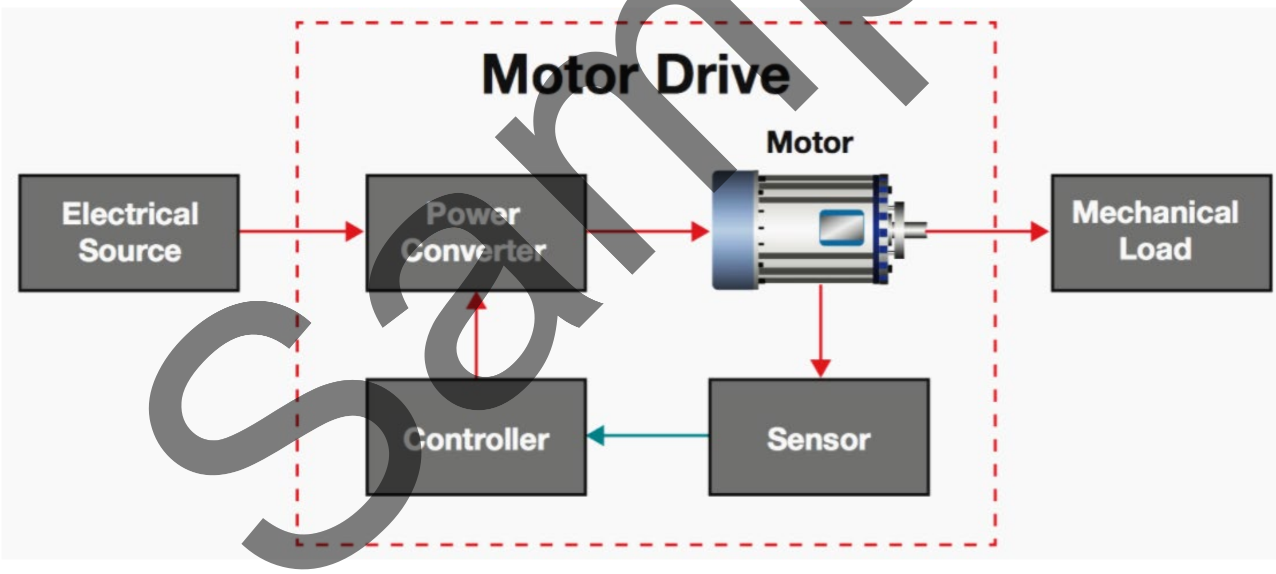


Figure 1. Block diagram of a motor drive system.

The main functions of the power converter circuit in the motor drive are:

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1 Switching topologies for AC/DC control circuits:

Ref: https://electrical-engineering-portal.com/systems-motion-motor-drive

2 Note: In general, non-linear elements, mainly refer to electronic switches: semiconductors used in commutation mode, whereas linear reactive elements refer to capacitors, inductances and mutual inductances or transformers. These reactive components are used for intermediate energy storage but also for voltage and current filtering. They generally represent an important part of the size, weight, and cost of the equipment.

1. The power converter transfers electrical energy from a source that could be of a given voltage, current, and at a certain frequency and phase it then converts these to provide the output characteristics of voltage, current, frequency, and phase required by the motor such that the required mechanical output is achieved.

2. The function of the controller shown above is to regulate the energy flow by means of feedback coming from the sensor block.

3. Low power signals from the motor are measured by sensors which typically measure the speed, motor torque and motor shaft position and these are relayed to the controller.

4. The controller tells the converter what it needs to be doing. A closed-loop feedback system is the method of comparing what is happening to the motor's required output and making the necessary adjustments to maintain the target output.

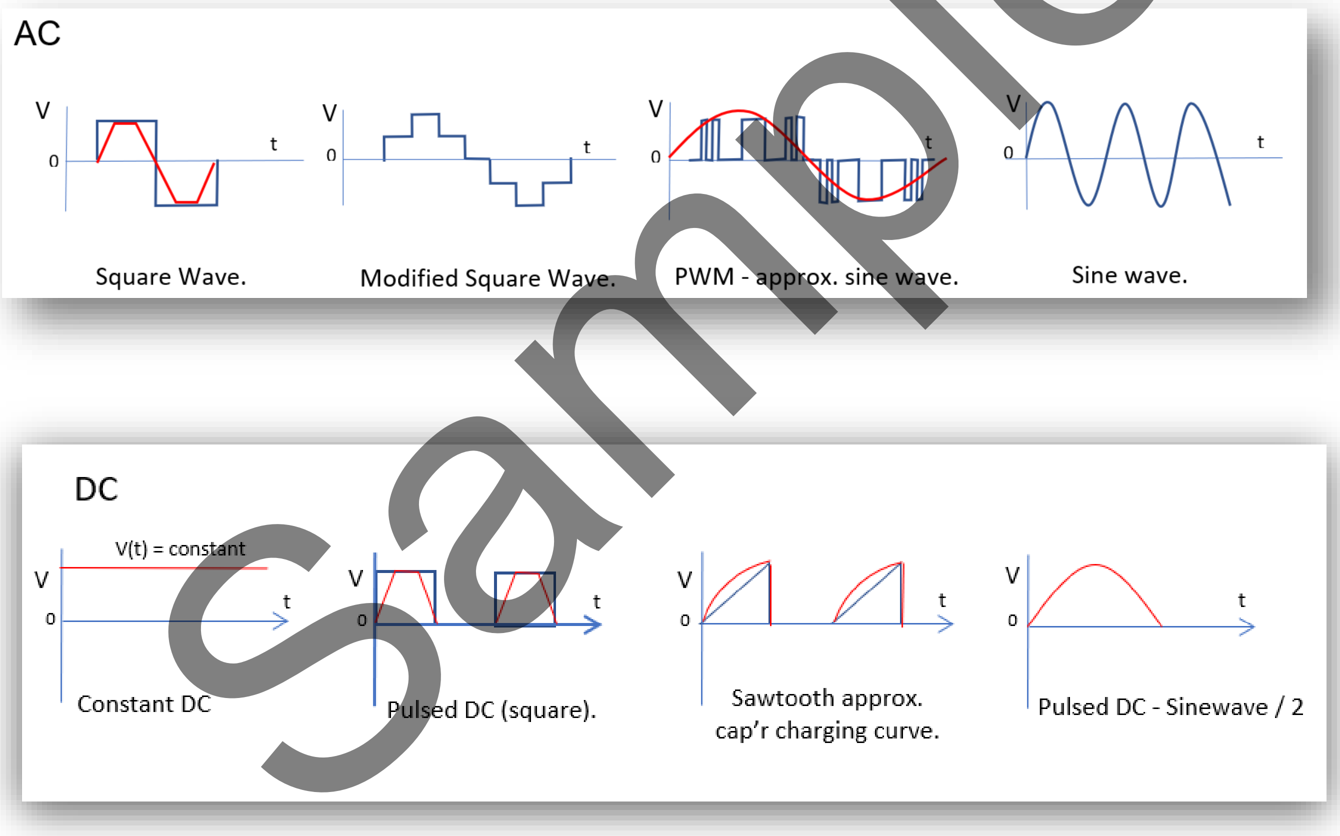


Fig 2. Typical AC and DC waveforms in power conversion circuits.

The above set of diagrams illustrate the most common types of AC and DC waveforms that we would expect to encounter. They help to visualise and explain what is happening to the voltage waveform over a particular time period and the waveform characteristics that may exist as either an input or as an output from a power convertor. The type of waveform will depend on the topology of the control circuit employed and the transformation required.

Control circuits that convert AC to DC or from DC to AC act as AC frequency changers. Modern electric drive systems, in which speed control of the electric motor is required, use these power supply converters.

These converters adapt the voltage and frequency of the power supply to the electric motor as required for the desired motor speed.

The basic components of the converters are **diodes** (electronic power components which allows for a flow of current in one direction only), transistors and **thyristors** (devices which conduct current in one direction and can be switched into the conducting state when a voltage of correct polarity is supplied to its main terminals and a trigger signal is applied to a gate terminal).

There are 4 Main types of converters which we will examine in turn: DC to DC, AC to DC, DC to AC and AC to AC

DC to DC converters

The DC-to-DC converter is a complex means of electronic control that can precisely control a D.C. motor's rotation, torque, and speed characteristics. DC unlike AC cannot be simply stepped up or down using a transformer. In many ways, however, a DC-DC converter can be regarded as the DC equivalent to an AC transformer.

Often referred to as Chopper circuits a basic **DC-DC converter** is a static power electronics device that converts a fixed DC input into a variable and controlled DC voltage/power output. It takes a source current and passes it through a "switching element". A chopper is fundamentally a high-speed semi-conductor switch which connects and disconnects the load from a source at a high rate to achieve a variable or chopped voltage at the output. It varies the voltage by controlling the varying angle to vary the duty cycle (defined as the ratio of ON time to the total time period). The output voltage of the chopper is in the form of pulses. The time ratio of the chopper can be controlled to vary the average voltage.

This chopper converts the signal into a square wave, which can be regarded as AC. This wave then passes through another filter, which converts it back into a **DC** signal having the appropriate voltage necessary to suit our requirements. Like the transformers of the AC circuit, choppers are used to step up and step down the DC power. They are used to change the fixed DC power input into a variable DC power supply for a range of devices and adjusted as required.

Whilst an AC/DC converter is powered from an A.C. supply, the D.C. chopper is powered from a D.C. power source. Both electronic controls produce a variable D.C. voltage that when applied to the D.C. motor's armature varies the armature current, hence, the motor speed.

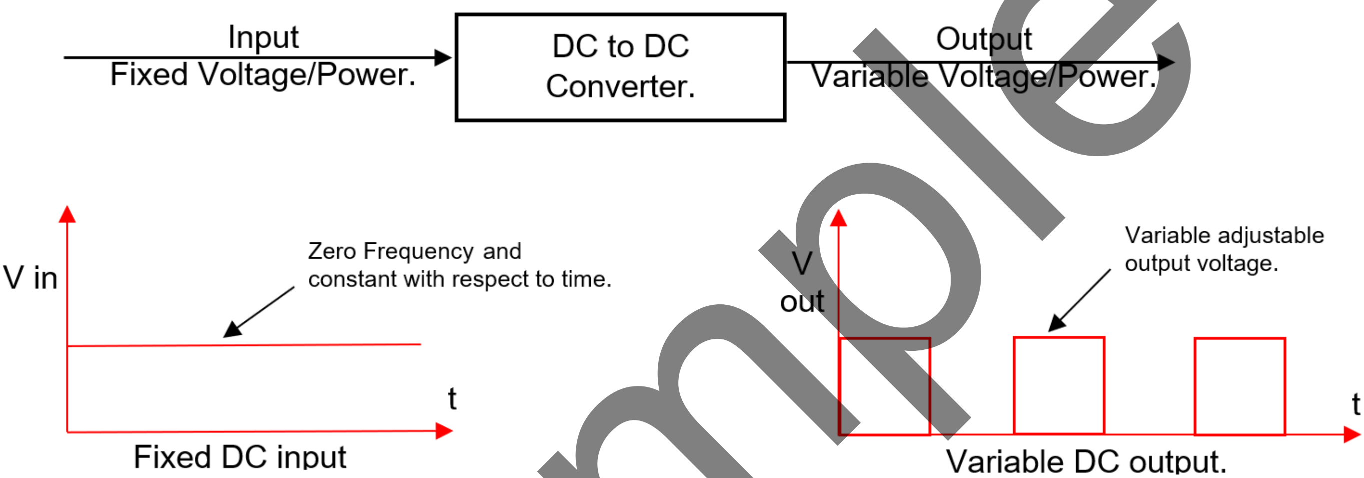
When the source is a DC supply (for example in a battery vehicle or a rapid transit system) a chopper-type converter is usually employed. Such applications include trolley cars, marine hoists, forklift trucks and mine haulers. Modern electric vehicles are likely to use choppers for their speed control and braking. Chopper systems offer smooth control, high efficiency, fast response, and regeneration.

The chopper-fed motor is, if anything, rather better than the phase-controlled type, because the armature current ripple can be less if a high chopping frequency is used.

The chopper can be utilised to increase or decrease the DC output voltage level and is sometimes referred to as a DC transformer.

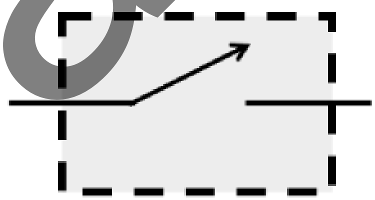
The diagrams below highlight the principle of operation for the DC-DC converter (chopper) and the associated waveforms for the source and resulting output voltage. We can consider the DC to DC converter here as a black box.

Chopper Symbol.



Fig, 3 DC to DC convertor diagrams.

When representing a chopper within a circuit diagram we use the following symbol:



As can be seen the chopper is simply represented as a switch enclosed within a dotted box. The chopper switch, when closed allows current to flow only one way, namely in the direction of the arrow as shown.

It is useful to note that chopper design is based around low power and high-power applications, in each case the devices used are as follows:

For low power they employ devices such as GTO, IGBT, Power BJT, Power MOSFET, for example, and for high power applications Thyristors and SCRs are generally used.

Note:

- GTO – **G**ate **T**urn **O**ff thyristors - Fully controllable.
- IGBT – **I**nsulated **G**ate **B**ipolar **T**ransistor used as a 3-terminal switch.

- Power BJT – Bipolar Junction Transistor uses two junctions and n and p-type charge carriers.
- Power MOSFET – A four terminal **M**etal **O**xide **F**ield **E**ffect **T**ransistor used for switching.
- SCR – **S**ilicon **C**ontrolled **R**ectifier a unidirectional device allowing current flow in one direction only.

Although we are mostly concerned with electronics as applied to electrical drives, it is worth noting that chopper circuits also find application in other power control as well as signal applications, e.g., solar and wind energy conversion, computers, commercial electronics, electronic instrument circuits and in aerospace on-board regulated DC power supplies.

The DC to DC type chopper circuit does not require a transformer unless it is linked to an AC circuit.

DC to DC step up and step down circuits.

As explained earlier the chopper circuit finds application where there is a need to either increase or decrease the output DC voltage relative to the input voltage. For this purpose we can envisage two different types of DC chopper circuit

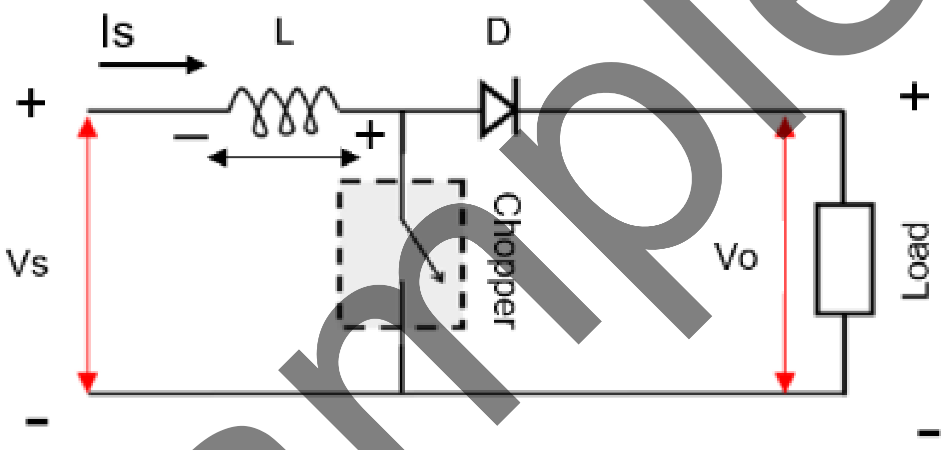


Fig. 4, Basic Step-up chopper circuit.

The step up chopper as seen in the above circuit diagram is often referrred to a "**Boost Converter**" and is used to provide an output or load voltage that is higher than the input / source voltage e.g. **Vo >= Vs.**

We know that the chopper is a high frequency switching device and therefore it operates in two states or modes of operation: one on which the chopper switch is open, the second where it is closed.

For the chopper switch in the closed position as shown below, the source voltage Vs is disconnected from the load and the closed circuit path is indicated by the blue arrows in the direction Vs (+) through inductor L and the chopper switch and back to Vs (-). The output across the load is zero.