Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit: 43 Further Electrical Machines and Drives

Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

DC Drives and their Industrial Applications

Table of Contents

GUIDANCE 3
Introduction to DC Drives and their Application to Emerging Areas. 4
Operating Modes of DC Drives 8
Analysis of Closed Loop Control of a DC Drive. 14
Transfer Functions an Overview: 23
Computer Simulation Modelling. 23

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 to DC Drives and their Application to Emerging Areas.

In this section we will examine the application of DC drives within areas such as smart grid and renewable energy sources.

The requirement for more sustainable electrical power supplies has led to a move away from conventional centralised AC electrical power generation and largescale transmission infrastructure. The traditional means of electricity generation are giving way to more decentralised systems in countries across the world where electrical transmission and distribution is more costly and often too difficult to achieve.

Even where traditional methods remain an option, there has been greater focus placed upon alternative technologies that are both renewable and decentralised, generating, and supplying electrical power more locally in relation to where it is required.

It is becoming more common for landowners, homeowners, commercial premises, and organisations to employ decentralised forms of renewable power generation on their land and property and so remove their dependence upon mains generated power supplies derived from fossil fuel, as the following diagram aims to illustrate:

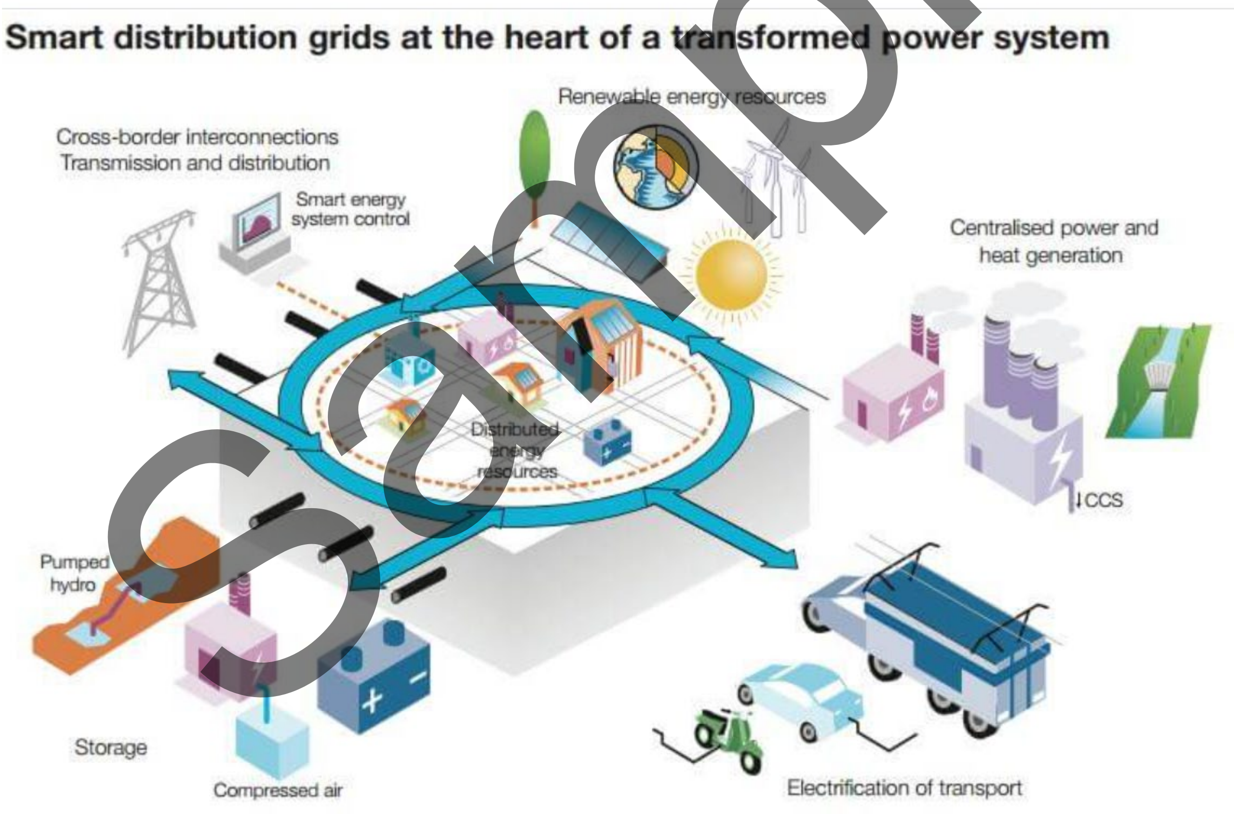

Fig 1 Distributed vs Centralised Power within a Smart Grid arrangement.

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Homeowners and industrial premises are capitalising on the many benefits offered by decentralised renewable energy schemes and combining these with more cost-effective electrical systems which also offer increased efficiency and reliability.

We can appreciate the number of industrial systems that rely upon electrical drives for their continued operation e.g., Liquid pumps, Compressors, HVAC fans, Conveyor belts, Machine presses, Machine tools etc.

The inherent fluctuation in power from renewable energy sources such as wind and photovoltaics has led to problems with power balancing. However, the idea of linking all these electrical systems together would help to make the electrical supply more energy efficient and stable, which partly explains why Intelligent DC grid systems are gaining in popularity.

Smart grids:

A smart grid may be defined as an electricity network enabling a two-way flow of electricity and data with digital communications technology, enabling us to detect, react, and pro-act to changes in usage and multiple issues. Smart grids enable electricity customers to become active participants in the manner electricity and data is generated and consumed.

A smart grid serves several purposes and the movement from traditional electric grids to smart grids is driven by multiple factors, including the deregulation of the energy market, evolutions in metering, changes on the level of electricity production, decentralisation (distributed energy), the advent of the involved ‘prosumer’, changing regulations, the rise of microgeneration and (isolated) microgrids, renewable energy mandates with more energy sources and new points where and purposes for which electricity is needed (e.g. electrical vehicle charging points).[1]

Some people in the industry do not talk about smart grids anymore. They see that term as referring to a first stage where advanced metering infrastructure (AMI) initiatives were deployed with first-generation smart meters. They prefer to speak about power grid modernization, given that this relates to far more elements than smart metering, e.g., sending data in two directions and adding power to the grid in the opposite direction.

Although many countries, regions, states etc. had already implemented smart metering initiatives a decade ago, there are still several countries where this has only just started. The challenges of grid players are mainly those seen within the decentralisation of energy generation and the transmission thereof.

Although mains electricity is generated and transmitted as AC, the application of DC has many advantages, not least quick starting and stopping and higher starting torque. They are good for applications with constant speed (although variable speeds can be achieved when combined with electronic control devices). Also, they are often regarded as being cheaper and easier to control than AC.

In addition to electrical drives, computers, smartphones, and LEDs all operate with DC and therefore need an adapter to convert AC power from the grid. Yet on the supply front, the situation is also changing. Whereas conventional power plants, such as coal-fired and nuclear, produce alternating current, locally installed and renewable energy resources such as photovoltaic plants — or, for that matter, electrochemical energy storage systems — only ever supply direct current.

DC drives broadly comprise the permanent magnet or field wound construction.

Their fundamental power source being typically derived from batteries, fuel cells, or unregulated-off grid photovoltaic systems.

1 *https://www.i-scoop.eu/industry-4-0/smart-grids-electrical-grid/*

Reference: https://techxplore.com/news/2020-06-dc-smart-grids-production.html

DC drive application in emerging areas

The need for more energy efficient drive systems and the increased focus on renewable sources of energy, is likely to ensure the future of DC drives for years to come.

DC is inherently compatible with solar and wind. Renewable sources generate power intermittently, requiring storage (batteries) in some applications as part of the system to provide a reliable supply. Solar PV is inherently a DC energy supply, as are batteries, making DC a more compatible interface. Modern electrical loads and electronic equipment operate on DC power. Most modern electrical and electronic loads require low-voltage DC power to operate.

Improvements in DC converter technologies, higher efficiency and power-to-size characteristics and advances in digital interfaces offer further advantages for the control and accuracy of DC drives systems.

DC drives remain an ideal choice for the control of DC motors used in heavy-industry applications such as metal processing, the pulp and paper industry, rubber, and plastic processing, lifting equipment and food processing. These drives are particularly suitable for two-quadrant and four-quadrant options (refer to later sections).

Electric cars & transportation

New electric vehicle infrastructure provides a large growth potential for the electrical transportation sector, leading to reduced carbon emissions and other environmental benefits. The growth in electric vehicle manufacture and sales has been considerable over the past few years and it is notable that electric vehicles with DC batteries can be charged using DC in a fraction of the time needed for AC charging.

New technologies support clean, local, distributed generation of DC power. Solar, wind, second-generation clean biomass, and innovative, low-cost fuel cell designs that use natural gas are ideal for green, local power generation. DC infrastructure will improve the integration of such resources into the grid and enhance their overall economic and environmental credentials.

Reference: https://www.tdworld.com/grid-innovations/transmission/article/20966512/get-ready-for-a-dc-future

Recent Developments

Large solar installations across large areas of land in countries around the world typically comprise a tracking system which fundamentally allows the solar panels to physically rotate and track the path of the sun for maximum energy utilisation. In today's distributed control design of PV tracking arrays, brushless DC motors with embedded intelligence can be networked with economic off-the-shelf PLCs having solar tracking functionality.

BLDC motors can be daisy-chain-controlled over a 500-m (1,640-ft.-long bus) using simple, inexpensive yet robust twisted pair shielded cabling.

Emerging Trends

With higher level integral BLDC motor embedded intelligence, a brushless motor can serve as master control to host and run programs in the event of network interruptions, such as returning the tracker to a safe position in a network outage. These motors may also use macro-like commands, wherein simple trigger messages initiate complex functions. In addition, diagnostic functions may take place over the network to report on motor status and health.

AC induction motors have been used in early solar tracking systems because they can draw power directly from the grid, but it is difficult to control AC motors at slow speeds necessary in most tracking applications. When an induction motor turns on and off in a step function to track the sun, it does not permit the most efficient continuous tracking and collection of solar energy.

Given that DC drives often take their supply from battery power source, this enables DC drives the greater opportunity for portability with the added advantages which this presents. It is therefore not so surprising that many industrial applications, including robotics, make widespread use of DC motors because of the ease of controlling speed and direction. They are capable of an infinite speed range, from full speed down to zero, with a wide range of loads. They can be used in many motion-control applications, for repetitive motion applications.

DC motors feature a high ratio of torque to inertia, and they can respond quickly to changes in control signals. A DC motor can be smoothly controlled to zero motion and instantly accelerated in the opposite direction without the need for complex power-switching circuitry. DC motors can be designed for continuous or intermittent duty and with or without brushes. Permanent-magnet brushless DC motors are usually more expensive than brush types, although they can provide advantages in power consumption and reliability. Brushless motors have a wound stator that surrounds a permanent-magnet rotor in contrast to the inverse arrangement of a brush-type DC motor. Without a commuter, brushless motors can operate more efficiently and at higher speeds than conventional DC motors. Most brushless DC motors run on a trapezoidal AC waveform, with some of these motors being sine wave driven to achieve smooth operation at lower speeds with low torque ripple.

Such levels of battery-operated drives and good accuracy and portability has seen the utilisation of DC drives across many sectors including space exploration, medicine, military applications, materials handling, manufacturing, warehouse storage, and logistics. All of these applications have experienced a wider application of DC drives and the technology continues to develop.

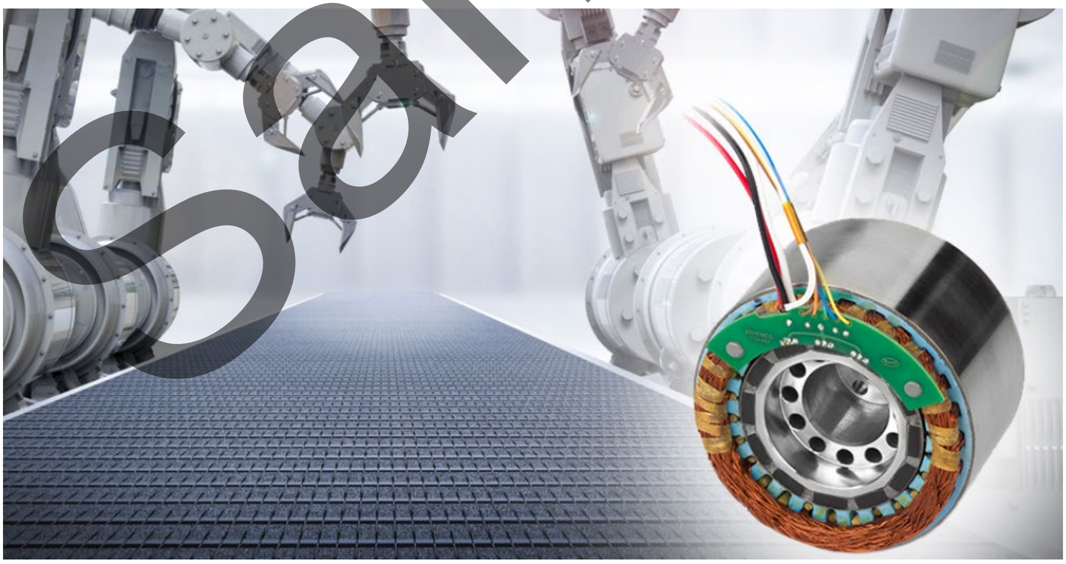

Figure 2 Frameless brushless DC (BLDC) motor suitable for multi-axis assembly robots in light manufacturing and semiconductor applications.

Information provided courtesy of Embedded motion and frameless motors in collaborative robots https://www.motioncontroltips.com/embedded-motion-control-and-frameless-motors-in-collaborative-robots/ L. Eitel - June 3, 2019

The compact size of these types of motor is essential to fitting inside articulating robot wrists, elbows, and shoulder axes. Motor robustness and optimized torque-thermal performance ensures reliable operation in continuous-duty settings.

Wind turbines

The generator in a wind turbine will produce alternating current (AC) electricity. Some turbines will incorporate an AC/DC/AC converter—which converts the AC to direct current (DC) with a rectifier and then back to AC with an inverter—to match the frequency and phase of the grid. Perhaps what is not so readily appreciated are the number of other types of drives which form part of a wind turbine assembly and which offer the degree of control necessary for the turbine to extract energy from the wind approaching the blades from various directions.

Operating Modes of DC drives

In this section we will examine single-phase drives, three-phase drives, chopper drives, two/four quadrant operation drives.

We know that DC drives can be split into two broad categories in relation to their main type of power supply, namely single phase and three phase and the quadrants within which they have been designed to perform.

As we probably know by now, the single-phase supply category can be further subdivided into:

- Single phase half wave converter drives
- Single phase full converter drives
- Single phase dual converter drives.

Single phase half wave and full wave rectification was explained in earlier workbooks.

There are several methods that we can choose to control the speed of a DC motor.

In this section we recall that the speed of the DC motor is proportional to the voltage. A practical way of controlling the speed of our motor is to vary the voltage. This can be achieved using a dual converter.

The single-phase dual converter drive comprise two converters connected back-to-back as shown.