Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit: 43 Further Electrical Machines and Drives

Unit Workbook 4

in a series of 4 for this unit

Learning Outcome 4

AC Drives and their Industrial Applications

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 to AC Drives and their Industrial Applications

It is important at this point to highlight the distinction between what we refer to as a motor and a drive.

Put simply, a motor is the mechanical or electrical device that generates the rotational or linear force used to power a machine. A drive on the other hand is the electronic device that harnesses and controls the electrical energy sent to the motor.

Types of AC Drives

AC motor drives are classified based on the type of AC motor being used. The most common types include induction, synchronous, sensorless vector, and servo drives.

Induction motors derive their name from the fact that current is induced into the rotor windings without any physical connection with the stator windings (which are directly connected to an AC power supply); adaptable to many different environments and capable of providing considerable power as well as variable speed control. Typically, there is "slip," or loss of exact speed tracking with induction motors.

Synchronous motors operate at constant speed up to full load. The rotor speed is equal to the speed of the rotating magnetic field of the stator; there is no slip. Reluctance and permanent magnet are the two major types of synchronous motors. A synchronous motor is often used where the exact speed of a motor must be maintained.

Sensorless vector drives employ independent control of both the voltage and frequency supplied to the motor for good speed control, and low-speed torque output approaching that of DC motors. Sensorless indicates that no feedback sensor such as an encoder or resolver is used.

Servo motors are typically permanent magnet synchronous motors that can often have low torque-to-inertia ratios for high acceleration ratings. They frequently employ brushless commutation with feedback provided by Hall Effect sensors, and sinusoidal winding excitation.

Fig, 1. Typical examples of AC drive units

AC motor drives can also be classified based on types of control functions (e.g., integral motion controllers, variable speed drives, motor speed controllers, etc.).

Design Specifications

There are a wide range of design specifications to consider when searching for AC motor drives. The most important of these include:

- Continuous current - the current applied to the motor during continuous operation.
- Supply voltage - the voltage supplied to the drive.
- Output voltage - the range of output voltages of the drive.
- Input frequency - the AC input frequency accepted by the device.
- Power - the rated power output of the drive motor system.
- Operating temperature - the operating temperature of the power supply.

Other important characteristics include the mounting configuration and accompanying features.

Mounting Configuration

Drive mounting configuration is important for compatibility with the motor system. Drives can be mounted in various ways based on the design, including onto a PCB (printed circuit board), PC board, panel, DIN rail, or rack. Other drives may be stand-alone devices or designed to be incorporated into specific products by original equipment manufacturers (OEMs).

Fig 2. Typical mounting arrangement of AC drive units within control cabinet.

Additional AC drive features:

AC motor drives may also include various features which may be important for certain applications. These include:

- **Regeneration** - Method of braking in which the motor is disconnected from the power supply and power generated from the rotating motor is sent back to the supply.

- **Programmability and configuration** - Device can be programmed with routine configurations and commands for greater functionality and process control.

- **Auto restart** - Drive is designed to automatically restart operation after a stall.

AC motors are used in abundance throughout industry, factories, infrastructure, utilities and building services. In modern society, the increasing global demand for electrical energy requires that we design and operate systems which combine low energy requirements with an efficient means of control.

In this unit we will examine the application of AC drives and their general industrial applications.

The question many might ask is: “Why do we need an AC drive if we already have an AC motor?

The simple answer to this question is that without an AC drive the AC motor when connected to its 3-phase supply will only run at the frequency indicated on the motor’s nameplate.

So, we can establish the motor speed from the basic equation $N_s = 60\,f/p$

Where f is the supply frequency and p represents the number of pole pairs. The factor 60 converts from seconds to minutes given that the frequency is typically expressed in cycles per second (Hertz).

e.g. A 50 Hz 4 pole motor will only run at 50 x 60 /2 = 1500 rpm

A 50 Hz 6 pole motor will only run at 50 x 60 /3 = 1000 rpm

A 50 Hz 8 pole motor will only run at 50 x 60 /4 = 750 rpm

A 50 Hz 2 pole motor will only run at 50 x 60 /1 = 3000 rpm

Note that the above speeds will be reduced further due to the amount of slip.

Furthermore, these speeds are not adjustable in the absence of any control. To adjust these speeds, we require an AC drive.

The reasons for installing an AC drive are largely related to the needs of the process/application. A modern air conditioning and heating system for example, is likely to require greater control over the flow of air over a wider range of ambient or operating conditions. An AC drive in this case can provide control over the motor speed and consequently the speed of the fan. Equally the speed of pumps, conveyors, cranes, hoists, and machine tools all benefit from the use of AC drives to provide greater control over motor speed and torque and hence provide a significant improvement in efficiency with changes in operational demands. An AC drive ensures that energy losses are kept to a minimum by ensuring that the energy supplied to the system is no greater than the system’s needs. This is very important given that energy costs have a significant impact on the running costs of a business.

Many different methods have been tried and tested over time to provide some degree of control over motors, these include gears, brakes, and clutches. All of which suffer from the type of inefficiencies with which engineers are only too familiar. Other methods include hydraulic and electro-mechanical control.

The development of high-quality electronic components has led to the availability and application of electronic speed and torque control of motors. AC drives are now synonymous with electronically controlled variable speed or variable frequency drives. AC drives are not such a new idea, they have been in use since the 1970’s. However greater improvements have resulted from the integration of electronic components with improved software and digital technology which has led to more compact and more efficient drive systems.

An AC drive is a device used to control the speed of an AC motor which it achieves by controlling the frequency of the voltage supplied to the motor. It does this by first converting 3 phase 50 Hz[1] AC power to DC power. Then, by various electronic switching devices (of the type we have previously encountered), it inverts this DC power into a pseudo sine wave 3 phase AC supply of adjustable frequency, for the connected motor. The frequency coming into the converter has a fixed frequency of 50 Hz (other regions differ). However, the adjustable frequency coming from the inverter and supplied to the motor can be varied to suit the specific application. The main components of a variable frequency drive (VFD) are a rectifier (also referred to as a converter), which converts AC voltage to DC voltage, a DC bus (also referred to as a DC link), which filters and stores the DC power, and an inverter, which converts the DC power back to AC power with the required frequency and voltage.

Induction Motor Drives and Closed Loop Control

We have already examined the induction motor in previous units. In this section we will look at the closed loop control of the induction motor AC drive. Remember that the induction motor is also referred to as an asynchronous motor in which the rotor speed rotates at a speed less than the rotating magnetic field. i.e., the synchronous speed.

A synchronous motor on the other hand is a machine where the rotor speed and synchronous speed are equal. The induction and synchronous motor types both belong to the AC class of motors.

In more simpler applications where we may be required to operate a fan or a pump then using a VFD with open loop control may be perfectly adequate. Provided that the ratio between the applied voltage and frequency remains constant, we will achieve a constant torque and a power that increases linearly with frequency up to the motor's rated frequency. This is illustrated in the following diagram.

[1] Most countries use 50Hz (50 Hertz or 50 cycles per second) as their AC frequency. The standard in the United States is 120V and 60Hz