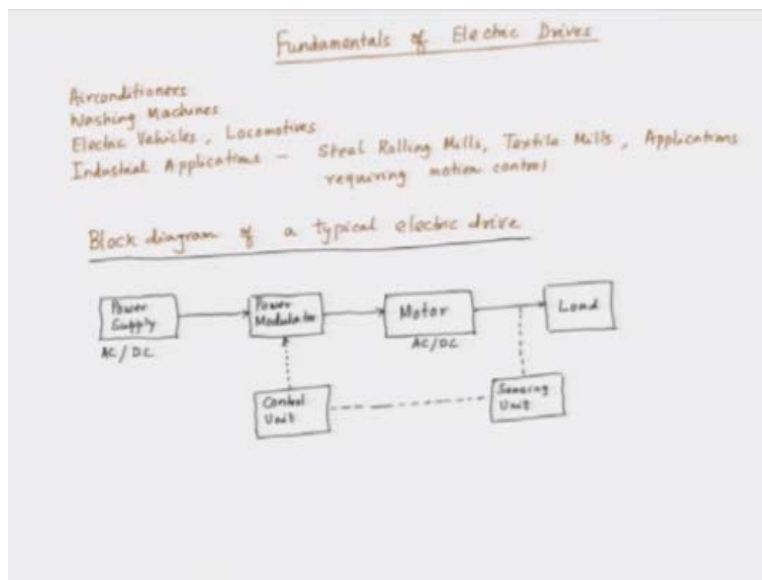


Fundamentals of Electric Drives
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Lecture – 01
Introduction to Electric Drives

Welcome to this NPTEL course on the fundamentals of electric drives. In this course, we will explore the control of various types of electric motors, primarily using solid-state devices. Electric drives play a crucial role in modern engineering, as they allow us to effectively manage the performance and operation of motors in a wide range of applications. So, let us begin with this course.

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Electric drives are integral to both everyday applications and industrial settings. Essentially, wherever there's a motor, you will find an electric drive in action. Take household appliances, for example: an air conditioner uses an electric drive to manage its motor. Other common examples include washing machines and various home appliances, all of which rely on electric drives to function efficiently. Beyond household applications, electric drives are critical in electric cars, electric vehicles, locomotives, trains, and a wide range of industrial systems.

In industrial environments, electric drives are used in high-power applications, such as steel rolling mills, textile mills, and any industry requiring precise motion control. These are just a few examples, but the scope is vast. Essentially, electric drives are employed in nearly all aspects of modern life where motion is involved, whether it's rotational motion or translational motion. Anytime motion is required, electric drives come into play.

Now, let's dive into the components of an electric drive system. We can think of this in terms of a block diagram of a typical electric drive. At the heart of any electric drive is the electric motor. The motor is responsible for generating the necessary motion, but it needs to be controlled and powered by a stable power supply.

The motor itself is the central component of the system, and it requires input from a power modulator to regulate the energy it receives. The power modulator is crucial as it adjusts the power supplied to the motor based on the motor's operational needs, and this power is sourced from an external power supply.

Let's start with the key component of the system: the electric motor. This motor forms the heart of the drive, and it's responsible for generating the motion required by the system. However, the motor doesn't operate on its own, it needs to receive power, which is provided through a device known as the power modulator. The power modulator feeds the motor by drawing energy from a power supply, and then the motor transfers this power to a load. This load, connected to the motor through mechanical coupling, represents the mechanical work being performed by the motor.

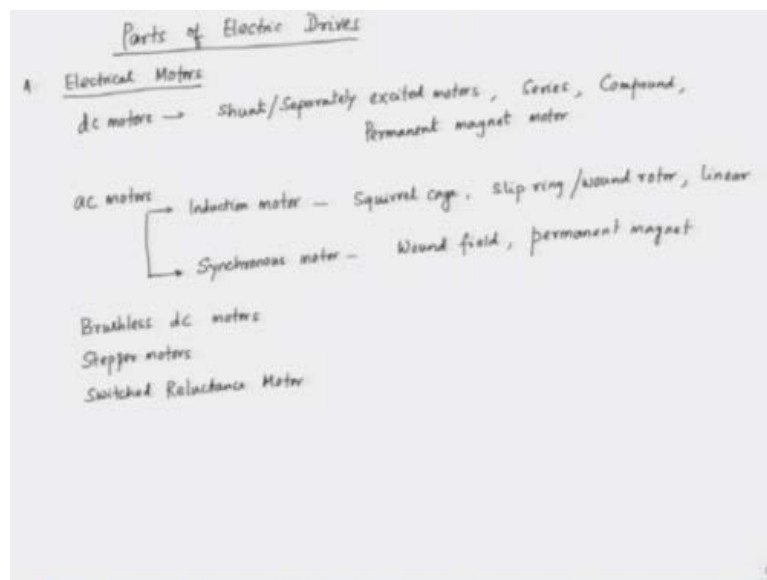
Now, controlling the motor is crucial, particularly when it comes to managing its speed and torque. To achieve this, the system must incorporate a closed-loop feedback mechanism. This feedback loop continuously monitors various parameters in the drive system. It includes sensors that detect performance metrics, a control unit that processes this information, and the control unit then adjusts the power modulator to regulate the motor's operation.

For instance, while the power supply may be fixed, the motor's speed and torque might need to be adjusted based on the load's requirements. Imagine you're driving an electric car or bus, the speed of the vehicle needs to be controlled. This control is achieved by the power modulator, which ensures that the power supply, whether it's AC or DC, matches the motor's needs.

The power supply can be either AC or DC, and similarly, the motor could be an AC motor, a DC motor, or even a special type of motor. The load, too, can vary, it could be any mechanical load. When all these components, the motor, load, power modulator, power source, and the closed-loop feedback system, work together, we refer to this as an electric drive.

Simply having a motor is not enough to define an electric drive. The system becomes an electric drive when we integrate the motor with the load, power modulator, power source, and feedback control. Now, to better understand the system, let's first take a closer look at the electric motor itself.

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When discussing the components of electric drives, the first and most crucial part is the electric motor. Electric motors come in various types depending on the specific application. For instance, you can have DC motors, AC motors, and even special types of motors. Let's start by considering a simple DC motor.

In the category of DC motors, there are several variations. You can have shunt motors or separately excited motors, series motors, compound motors, and permanent magnet motors, each with distinct characteristics and uses.

Similarly, AC motors also come in different types. One of the most commonly used is the induction

motor, which itself can be further classified into subtypes. For example, we have squirrel cage induction motors, slip ring (or wound rotor) induction motors, and even linear induction motors. Induction motors are highly prevalent in industrial applications due to their reliability and efficiency.

Another significant type of AC motor is the synchronous motor. Synchronous motors are generally reserved for high-power applications. There are several types of synchronous motors, such as wound field motors, where the field windings are excited by a DC supply. In this configuration, the DC current creates a magnetizing flux in the motor, enabling it to function effectively.

In some applications, particularly in electric vehicles, we use a special type of synchronous motor called a permanent magnet synchronous motor. In this case, the wound field is replaced by permanent magnets in the rotor, providing the necessary excitation for the motor. These are referred to as permanent magnet synchronous motors, and they are known for their high efficiency and compact size.

In addition to the conventional DC and AC motors, there exists a category of special motors known as brushless DC motors. Traditional DC motors typically have brushes that require regular maintenance. These brushes, along with the commutator, tend to wear out over time and must be replaced. Moreover, they can create sparking during operation, which is not ideal for longevity and efficiency.

To address these maintenance issues, brushless DC motors were developed. These innovative motors do not utilize a mechanical commutator or brushes. Instead, they rely on an electronic inverter to perform the commutation function, making them virtually maintenance-free. The inverter is a crucial component of brushless DC motors, allowing for smooth and efficient operation without the downsides associated with traditional brushes.

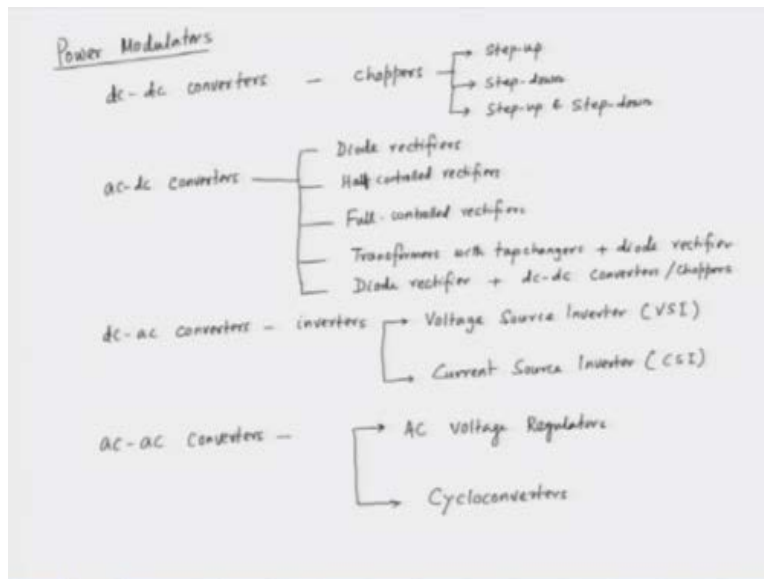
Another fascinating type of motor is the stepper motor, which is extensively used in robotics and control applications. Stepper motors operate without the need for closed-loop feedback, making them suitable for precise control in various applications.

Additionally, we have switched reluctance motors, which are particularly advantageous in space applications. These motors are characterized by their lightweight rotor, which results in very low

inertia. This allows them to be easily accelerated and decelerated, making them ideal for environments where weight and responsiveness are critical.

These various classifications of electric motors highlight the diversity and specialization available in the field. Now, let's move on to the next critical component of electric drives: the power modulator.

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The power modulators play a crucial role in matching the requirements of the motor with the appropriate power supply. This power supply can be either AC or DC, and the power modulator's function is to convert one form of electric energy into another.

Let's start by examining DC to DC converters, which are also known as choppers. These modulators can either step up the voltage (step-up chopper) or step down the voltage (step-down chopper), and there are also configurations that combine both step-up and step-down functionalities. These converters effectively change DC voltage levels as needed.

Next, we have converters that convert AC to DC. These converters can take various forms, such as simple diode rectifiers or more advanced controlled rectifiers. The diode rectifiers convert AC to rectified DC, while controlled rectifiers are designed to change AC into variable DC. Within this category, we can find half-controlled rectifiers and fully controlled rectifiers. Additionally, we

can employ transformers with tap changers alongside diode rectifiers to manage the conversion process more effectively.

There are also configurations that integrate diode rectifiers with DC to DC converters or choppers. These various types of AC to DC converters are essential when working with an AC supply, let's say, for instance, a single-phase AC supply, while needing to power a DC motor. In such cases, the power modulator functions as the AC to DC converter, which could be through uncontrolled rectifiers, half-controlled rectifiers, full-controlled rectifiers, or other combinations. So, power modulators are vital for ensuring that the electric drive system receives the correct form and level of electrical energy required for efficient operation.

Next, we encounter another category of power modulators designed to convert DC to AC. In many applications, such as solar energy systems, the generated energy is in the form of DC, but we may need to drive an AC motor, like an induction motor. In such cases, we utilize DC to AC converters, commonly referred to as inverters.

Inverters can be classified into two main types: voltage source inverters (abbreviated as VSI) and current source inverters (CSI). Both types serve the essential function of transforming DC supply into AC supply suitable for operating AC motors.

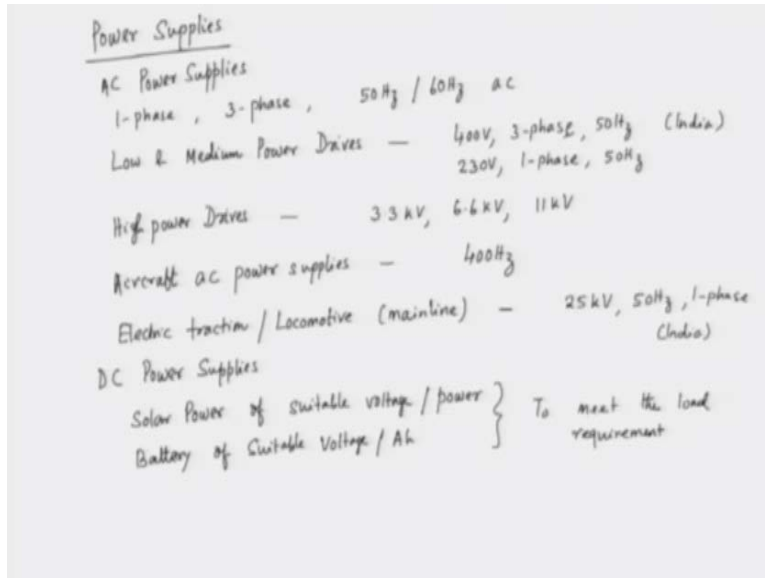
Now, let's discuss the last category of power modulators, which convert AC to AC. In some scenarios, we have a fixed voltage and frequency AC supply, but we require either a variable voltage with a fixed frequency or a variable voltage and frequency. For these requirements, we employ AC to AC converters.

One common type of AC to AC converter is the AC voltage regulator. These regulators take fixed frequency and fixed voltage input and convert it into variable voltage while maintaining the same frequency. Additionally, we have a type of converter known as cycloconverters. Cycloconverters are capable of converting fixed AC with a fixed voltage and frequency into variable voltage and variable frequency, making them particularly versatile for specific applications.

In summary, these power modulators are vital for effectively controlling electric motors. Having discussed the electric motors and power modulators, we now turn our attention to another critical component of electric drives: the power supply. Power supplies can vary widely; they can be AC

or DC, single-phase or three-phase, and they can operate at various voltage levels. We will briefly explore the different types of power supplies available in electric drive systems.

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When discussing power supplies, it's important to note that AC power supply is predominantly used due to its remarkable versatility. AC power can be easily stepped up for long-distance transmission and subsequently stepped down for localized use. This adaptability allows AC power supplies to be available at various voltage and frequency levels.

In residential applications, we commonly encounter single-phase AC power, while three-phase power supplies are standard in industrial settings. In India, for instance, the typical frequency is 50 Hz, although some regions may operate at 60 Hz. For low- and medium-power motors, the standard voltage is primarily 400 volts in three-phase systems at 50 Hz or 230 volts in single-phase systems, also at 50 Hz.

However, when dealing with high-power motors, we need to use higher voltage power supplies to meet the substantial power requirements. These can range from 3.3 kV to 6.6 kV, and even up to 11 kV, allowing motors to be adequately powered from these high-voltage sources.

In specialized applications, such as aerospace or space exploration, the frequency diverges from the conventional 50 Hz. For aircraft applications, we utilize a 400 Hz power supply. This higher

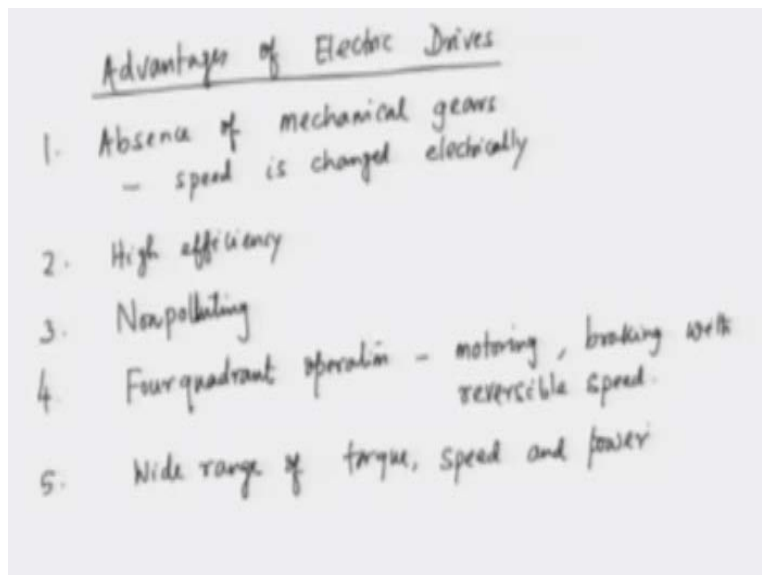
frequency offers significant advantages, as it allows for a reduction in the weight and volume of magnetic components, making it particularly beneficial for aircraft and space applications.

For electric traction, especially in locomotives and mainline trains, the power supply typically used is 25 kV at 50 Hz, single-phase. This variety of AC power supplies accommodates low, medium, and high-power applications. Therefore, whenever we have an AC power supply, it is crucial to employ suitable power modulators to align with the specific requirements of the motor and load.

When we discuss DC power supplies, it's important to note that they are commonly sourced from batteries. These batteries can supply various voltages, such as 48 volts or 100 volts, depending on the application. With the increasing availability of solar power, we can also obtain DC voltage from solar energy sources. Therefore, for DC power supplies, we can utilize solar power systems with suitable voltage and power ratings, or we can rely on batteries that meet the necessary voltage and ampere-hour requirements to effectively support the load.

Once we have established the available power supplies, we must select one that is appropriate for a given application and employ a suitable power modulator to ensure compatibility with the motor.

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Now, let's briefly explore the advantages of electric drives. One significant benefit of controlling an electric motor through a power converter or power modulator is that it eliminates the need for

a gearbox. In conventional vehicles, gears are essential for adjusting speed. However, electric vehicles, including electric locomotives, can operate without any gears at all. This absence of gears is a substantial advantage, simplifying the overall design and operation of electric drive systems.

In this segment, we will explore the advantages of electric drives. The foremost advantage is the absence of mechanical gears. Why is this significant? Because the speed adjustment occurs electrically, eliminating the need for traditional gear systems.

Another key advantage is the high efficiency of power converters. These converters operate at exceptional efficiency, which in turn enhances the overall efficiency of the electric drive system. Additionally, electric vehicles are non-polluting; they do not emit any harmful effluents. This means that during operation, electric vehicles run quietly and do not release harmful gases, making them an environmentally friendly option.

We also have what is known as four-quadrant operation. This feature allows electric drives to operate in motoring and braking modes, as well as to reverse speed. Furthermore, electric drives provide a wide range of torque, speed, and power outputs.

For instance, consider a computer fan, which is a type of electric drive that consumes just a few watts. In contrast, a mixer grinder may use a few hundred watts, while an air conditioner can require several thousand watts. In industrial applications, electric drives can reach hundreds of kilowatts, and for traction applications, they can even operate at the megawatt level.

This scalability means that we can easily transition from very low-power applications to high-power ones simply by adjusting the ratings of the power converter and the power supply. So, we conclude the first lecture today and will be discussing more things in the next lecture.