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Department of Electrical and Electronics Engineering

Bridge Course

On

Utilization of Electrical Energy

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UTILIZATION OF ELECTRICAL ENERGY

Power engineering, also called **power systems engineering**, is a subfield of electrical engineering that deals with the generation, transmission, distribution and utilization of electric power, and the electrical apparatus connected to such systems.

An **electric power system** is a network of electrical components deployed to supply, transfer, and use electric power. An example of an electric power system is the *the grid* that provides power to an extended area. An electrical grid power system can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centers to the load centers, and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power—the standard for large-scale power transmission and distribution across the modern world. Specialized power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners and automobiles.

Generation

The production of bulk electric power for industrial, residential, and rural use. Although limited amounts of electricity can be generated by many means, including chemical reaction (as in batteries) and engine driven generators (as in automobiles and airplanes), electric power generation generally implies large-scale production of electric power in stationary plants designed for that purpose. The generating units in these plants convert energy from falling water, coal, natural gas, oil, and nuclear fuels to electric energy. Most electric generators are driven either by hydraulic turbines, for conversion of falling water energy; or by steam or gas turbines, for conversion of fuel energy. Limited use is being made of geothermal energy, and developmental work is progressing in the use of solar energy in its various forms.

Transmission

Electric power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. The interconnected lines which facilitate this movement are known as a transmission network. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. The combined transmission and distribution network is known as the "power grid".

Distribution

Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines at this voltage. Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level.

Electric power

Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second. Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries. It is usually supplied to businesses and homes by the electric power industry through an electric power grid. Electric power is usually sold by the kilowatt hour (3.6 MJ) which is the product of power in kilowatts multiplied by running time in hours. Electric utilities measure power using an electricity meter, which keeps a running total of the electric energy delivered to a customer.

A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another. As a result, power supplies are sometimes referred to as electric power converters. Some power supplies are discrete, stand-alone devices, whereas others are built into larger devices along with their loads. Examples of the latter include power supplies found in desktop computers and consumer electronics devices.

DC power supply

A DC power supply is one that supplies a constant DC voltage to its load. Depending on its design, a DC power supply may be powered from a DC source or from an AC source such as the power mains.

AC power supply

An AC power supply typically takes the voltage from a wall outlet (mains supply) and lowers it to the desired voltage. Some filtering may take place as well.

In modern use, AC power supplies can be divided into single phase and three phase systems. "The primary difference between single phase and three phase AC power is the constancy of delivery." AC power Supplies can also be used to change the frequency as well as the voltage, they are often used by manufacturers to check the suitability of their products for use in other countries. 230V 50 Hz or 115 60 Hz or even 400 Hz for avionics testing.

Light

Light is a transverse, electromagnetic wave that can be seen by humans. The wave nature of light was first illustrated through experiments on diffraction and interference. Like all electromagnetic waves, light can travel through a vacuum. The transverse nature of light can be demonstrated through polarization.

Sources : Light is produced by one of two methods…

Incandescence is the emission of light from "hot" matter (T ≳ 800 K).

Luminescence is the emission of light when excited electrons fall to lower energy levels (in matter that may or may not be "hot").

Flux

Flux is the presence of a force field in a specified physical medium, or the flow of energy through a surface. In electronics, the term applies to any electrostatic field and any magnetic field

Magnetic field (B)

$$\text{Magnetic flux} = \Phi = B\,A$$

Area perpendicular to magnetic field B (A)

Electromotive force (emf)

Electromotive force, also called emf (measured in volts), is the voltage developed by any source of electrical energy such as a battery or dynamo. It is generally defined as the electrical potential for a source in a circuit. A device that supplies electrical energy is called electromotive force or emf. Emfs convert chemical, mechanical, and other forms of energy into electrical energy. The product of such a device is also known as emf.

Voltage

Voltage, electric potential difference, electric pressure or electric tension (formally denoted ΔV or ΔU, but more often simply as V or U, for instance in the context of Ohm's or Kirchhoff's circuit laws) is the difference in electric potential energy between two points per unit electric charge. The voltage between two points is equal to the work done per unit of charge against a static electric field to move the test charge between two points. This is measured in units of *volts* (a joule per coulomb).

Electric current

An **electric current** is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte, or by both ions and electrons The SI unit for measuring an electric current is the ampere, which is the flow of electric charge across a surface at the rate of one coulomb per second. Electric current is measured using a device called an ammeter.

Torque

Torque, moment, or moment of force is rotational force Just as a linear force is a push or a pull, a torque can be thought of as a twist to an object. Mathematically, torque is defined as the cross product of the vector by which the force's application point is offset relative to the fixed suspension point (distance vector) and the force vector, which tends to produce rotational motion.The magnitude of torque depends on three quantities: the force applied, the length of the *lever arm* connecting the axis to the point of force application, and the angle between the force vector and the lever arm.

Force

In physics, a **force** is any interaction that, when unopposed, will change the motion of an object. A force can cause an object with mass to change its velocity (which includes to begin moving from a state of rest), i.e., to accelerate. Force can also be described intuitively as a push or a pull. A force has both magnitude and direction, making it a vector quantity. It is measured in the SI unit of newtons and represented by the symbol F.

Faraday's Laws

Faraday's First Law

Any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called induced emf and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current. Method to change magnetic field:

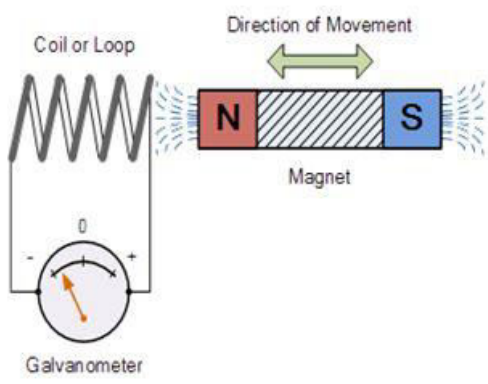
By moving a magnet towards or away from the coil,By moving the coil into or out of the magnetic field.

By changing the area of a coil placed in the magnetic field,By rotating the coil relative to the magnet.

Faraday's Second Law

It states that the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil. The flux linkage of the coil is the product of number of turns in the coil and flux associated with the coil.

Faraday Law Formula:



Consider a magnet approaching towards a coil. Here we consider two instants at time T_1 and time T_2.

Flux linkage with the coil at time, $T_1 = N\Phi_1$ Wb

Flux linkage with the coil at time, $T_2 = N\Phi_2$ wb

Change in flux linkage = $N(\Phi_2 - \Phi_1)$

Let this change in flux linkage be, $\Phi = \Phi_2 - \Phi_1$

So, the Change in flux linkage = $N\Phi$

Now the rate of change of flux linkage = $N\Phi / t$

Take derivative on right hand side we will get

The rate of change of flux linkage = $Nd\Phi/dt$

But according to Faraday's law of electromagnetic induction, the rate of change of flux linkage is equal to induced emf.

$$E = N\frac{d\phi}{dt}$$

.

Considering Lenz's Law

$$E = -N\frac{d\phi}{dt}$$

. Where, flux Φ in Wb = B.A ,B = magnetic field strength,A = area of the coil

Electrolysis

In chemistry and manufacturing, electrolysis is a technique that uses a direct electric current (DC) to drive an otherwise non-spontaneous chemical reaction. Electrolysis is commercially important as a stage in the separation of elements from naturally occurring sources such as ores using an electrolytic cell. The voltage that is needed for electrolysis to occur is called the decomposition potential.

Faraday's laws of electrolysis

Main article: Faraday's laws of electrolysis

First law of electrolysis

In 1832, Michael Faraday reported that the quantity of elements separated by passing an electric current through a molten or dissolved salt is proportional to the quantity of electric charge passed through the circuit. This became the basis of the first law of electrolysis: $m=k*q$ (or) $m=e*Q$. where; e is known as electrochemical equivalent of the metal deposited or of the gas liberated at the electrode.

Second law of electrolysis

Faraday discovered that when the same amount of current is passed through different electrolytes/elements connected in series, the mass of substance liberated/deposited at the electrodes is directly proportional to their equivalent weight.

Electrode

An electrode is an electrical conductor used to make contact with a nonmetallic part of a circuit (e.g. a semiconductor, an electrolyte, a vacuum or air).

Sag

Sag can be defined as "The difference in level between the points of supports and the lowest point on the conductor is known as sag

Tension

Tension on the conductor is inversely proportional to sag.If the tension is more the conductors are connected very tightly between the tower structure and hence sag is less.On the other hand is tension is less the conductors are connected loosely hands sag is more.

Supplies

All power systems have one or more sources of power. For some power systems, the source of power is external to the system but for others it is part of the system itself—it is these internal power sources that are discussed in the remainder of this section. Direct current power can be supplied by batteries, fuel cells or photovoltaic cells. Alternating current power is typically supplied by a rotor that spins in a magnetic field in a device known as a turbo generator. There have been a wide range of techniques used to spin a turbine's rotor, from steam heated using fossil fuel (including coal, gas and oil) or nuclear energy, falling water (hydroelectric power) and wind (wind power).

Loads

Power systems deliver energy to loads that perform a function. These loads range from household appliances to industrial machinery. Most loads expect a certain voltage and, for alternating current devices, a certain frequency and number of phases. The appliances found in your home, for example, will typically be single-phase operating at 50 or 60 Hz with a voltage between 110 and 260 volts (depending on national standards). An exception exists for centralized air conditioning systems as these are now typically three-phase because this allows them to operate more efficiently. All devices in your house will also have a wattage, this specifies the amount of power the device consumes. At any one time, the net amount of power consumed by the loads on a power system must equal the net amount of power produced by the supplies less the power lost in transmission

Conductors

Conductors carry power from the generators to the load. In a grid, conductors may be classified as belonging to the transmission system, which carries large amounts of power at high voltages (typically more than 69 kV) from the generating centers to the load centers, or the distribution system, which feeds smaller amounts of power at lower voltages (typically less than 69 kV) from the load centers to nearby homes and industry.

Choice of conductors is based upon considerations such as cost, transmission losses and other desirable characteristics of the metal like tensile strength. Copper, with lower resistivity than Aluminum, was the conductor of choice for most power systems. However, Aluminum has lower cost for the same current carrying capacity and is the primary metal used for transmission line conductors. Overhead line conductors may be reinforced with steel or aluminum alloys

Resistance

Resistance is an electrical quantity that measures how the device or material reduces the electric current flow through it. The resistance is measured in units of ohms (Ω).

Capacitors and Reactors

The majority of the load in a typical AC power system is inductive; the current lags behind the voltage. Since the voltage and current are out-of-phase, this leads to the emergence of an "imaginary" form of power known as reactive power. Reactive power does no measurable work but is transmitted back and forth between the reactive power source and load every cycle. This reactive power can be provided by the generators themselves, through the adjustment of generator excitation, but it is often cheaper to provide it through capacitors, hence capacitors are often placed near inductive loads to reduce current demand on the power system (i.e., increase the power factor), which may never exceed 1.0, and which represents a purely resistive load. Power factor correction may be applied at a central substation, through the use of so-called "synchronous condensers" (synchronous machines which act as condensers which are variable in VAR value, through the adjustment of machine excitation) or adjacent to large loads, through the use of so-called "static condensers" (condensers which are fixed in VAR value).

Reactors consume reactive power and are used to regulate voltage on long transmission lines. In light load conditions, where the loading on transmission lines is well below the surge impedance loading, the efficiency of the power system may actually be improved by switching in reactors. Reactors installed in series in a power system also limit rushes of current flow, small reactors are therefore almost always installed in series with capacitors to limit the current rush associated with switching in a capacitor. Series reactors can also be used to limit fault currents.

Capacitors and reactors are switched by circuit breakers, which results in moderately large steps in reactive power. A solution comes in the form of static VAR compensators and static synchronous compensators. Briefly, static VAR compensators work by switching in capacitors using thyristors as opposed to circuit breakers allowing capacitors to be switched-in and switched-out within a single cycle. This provides a far more refined response than circuit breaker switched capacitors. Static synchronous compensators take a step further by achieving reactive power adjustments using only power electronics.

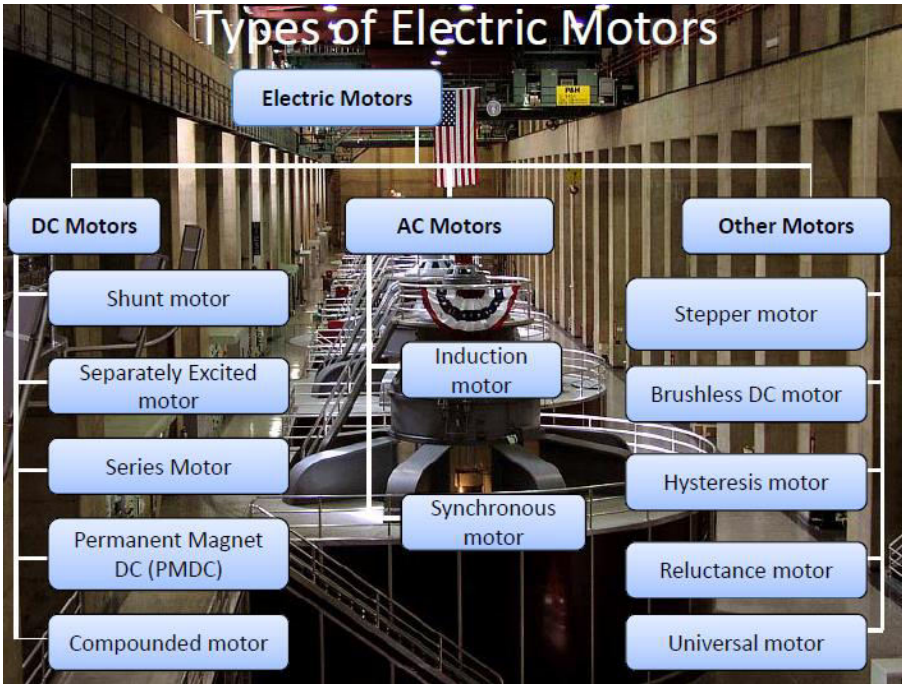
Protective devices

Power systems contain protective devices to prevent injury or damage during failures. The quintessential protective device is the fuse. When the current through a fuse exceeds a certain threshold, the fuse element melts, producing an arc across the resulting gap that is then extinguished, interrupting the circuit. Given that fuses can be built as the weak point of a system, fuses are ideal for protecting circuitry from damage. Fuses however have two problems: First, after they have functioned, fuses must be replaced as they cannot be reset. This can prove inconvenient if the fuse is at a remote site or a spare fuse is not on hand. And second, fuses are typically inadequate as the sole safety device in most power systems as they allow current flows well in excess of that that would prove lethal to a human or animal.

Base Load

The **base load** on a grid is the minimum level of demand on an electrical grid over a span of time, for example, one week. Base load power sources are power stations which can economically generate the electrical power needed to satisfy this minimum demand. Because they have a relatively high annual contribution to the energy supply, they are designed with features to minimize fuel cost. Daily peaks in grid load are met with generating plants that may have higher fuel costs, but which operate for only a part of a day.

Types of Motors



Load balancing

Load balancing, **load matching**, or **daily peak demand reserve** refers to the use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises. The goal would be for the power supply system to see a load factor of 1.

Grid energy storage stores electricity within the transmission grid beyond the customer. Alternatively, the storage can be distributed and involve the customer, for example in storage heaters running demand-response tariffs such as the United Kingdom's Economy 7, or in a vehicle-to-grid system to use storage from electric vehicles during peak times and then replenish it during off peak times. These require incentives for consumers to participate, usually by offering cheaper rates for off peak electricity.

Power Factor : Definition and calculation

AC power flow has two components:

- Real power or active power (P), expressed in watts (W)

- Reactive power (Q), usually expressed in reactive volt-amperes (var)

These are combined to the complex power (S) expressed volt-amperes (VA). The magnitude of the complex power is the apparent power (|S|), also expressed in volt-amperes (VA).The VA and var are non-SI units mathematically identical to the watt, but are used in engineering practice instead of the watt in order to state what quantity is being expressed. The SI explicitly disallows using units for this purpose or as the only source of information about a physical quantity as used.

Power Factor is defined as the ratio of real power to apparent power. As power is transferred along a transmission line, it does not consist purely of real power that can do work once transferred to the load, but rather consists of a combination of real and reactive power, called apparent power.

Load factor

In electrical engineering the **load factor** is defined as the average load divided by the peak load in a specified time period.[1] It is a measure of variability of consumption or generation; a low load factor indicates that load is highly variable, whereas consumers or generators with steady consumption or supply will have a high load factor.

Commercial power systems

Commercial power systems such as shopping centers or high-rise buildings are larger in scale than residential systems. Electrical designs for larger commercial systems are usually studied for load flow, short-circuit fault levels, and voltage drop for steady-state loads and during starting of large motors. The objectives of the studies are to assure proper equipment and conductor sizing, and to coordinate protective devices so that minimal disruption is cause when a fault is cleared. Large commercial installations will have an orderly system of sub-panels, separate from the main distribution board to allow for better system protection and more efficient electrical installation.

Residential power systems

Residential dwellings almost always take supply from the low voltage distribution lines or cables that run past the dwelling. These operate at voltages of between 110 and 260 volts (phase-to-earth) depending upon national standards. A few decades ago small dwellings would be fed a single phase using a dedicated two-core service cable (one core for the active phase and one core for the neutral return). The active line would then be run through a main isolating switch in the fuse box and then split into one or more circuits to feed lighting and appliances inside the house. By convention, the lighting and appliance circuits are kept separate so the failure of an appliance does not leave the dwelling's occupants in the dark. All circuits would be fused with an appropriate fuse based upon the wire size used for that circuit. Circuits would have both an active and neutral wire with both the lighting and power sockets being connected in parallel. Sockets would also be provided with a protective earth. This would be made available to appliances to connect to any metallic casing. If this casing were to become live, the theory is the connection to earth would cause an RCD or fuse to trip—thus preventing the future electrocution of an occupant handling the appliance. Earthing systems vary between regions, but in countries such as the United Kingdom and Australia both the protective earth and neutral line would be earthed together near the fuse box before the main isolating switch and the neutral earthed once again back at the distribution transformer.

Losses in Electrical Power Systems

In an electrical or electronic circuit, part of the energy in play is dissipated by unwanted effects, including energy lost by unwanted heating of resistive components (electricity is also used for the intention of heating, which is not a loss), the effect of parasitic elements (resistance, capacitance, and inductance), skin effect, losses in the windings and cores of transformers due to resistive heating and magnetic losses caused by eddy currents, hysteresis,[1] unwanted radiation, dielectric loss, corona discharge, and other effects.

Electric Power Efficiency

Power efficiency

Power efficiency is defined as the ratio of the output power divided by the input power:

$\eta = 100\% \cdot P_{out} / P_{in}$

η is the efficiency in percent (%).

P_{in} is the input power consumption in watts (W).

P_{out} is the output power or actual work in watts (W).