Université Mostefa Ben Boulaïd-Batna 2

Faculté de Technologie

Département d'Electrotechnique

M^{r} Bachir ABDELHADI
Professeur

M^{elle} Mouna ABDELHADI
Vacataire

Anglais Technique et Terminologie

Spécialités:

Machines Électriques –ME-
Energies Renouvelables –ER-
Réseaux Electriques –RE-
Electromécanique –ELM-
Electrotechnique Industrielle –EI-

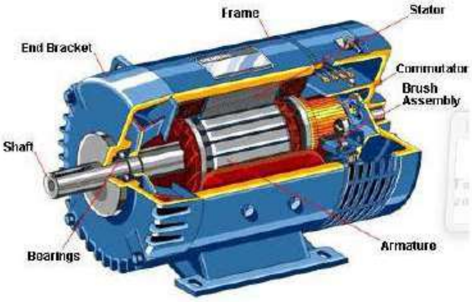
Série "Documents pédagogiques et didactiques"

Année Universitaire
2020/2021

Document pédagogique élaboré dans le cadre des dispositifs du décret exécutif n° 90-365 du 10/11/1990 relatif à l'élaboration des supports pédagogiques et didactiques

Part One:

Basic Electrical Terminologies and Definitions



Quantities and Units

All engineering disciplines deal with physical quantities and use units to measure those quantities. In electrical engineering the main quantities are charge, current, voltage and resistance. These are measured in coulombs, amps, volts and ohms respectively. Charge is the property of being electrically charged. Current is a flow of electrical charged particles. Voltage is the potential difference caused by two areas of differently charged material. Resistance describes a material's resistance to the flow of current.

Electrical Devices

In addition to the basic and familiar wires, batteries and light-bulbs; electrical engineers use a wide range of less well-known electrical devices. These include resistors, capacitors, inductors, diodes and transistors. Resistors are simply sections of wire with particular known resistances. Capacitors store energy in an electrical field. Inductors store energy in a magnetic field. Diodes allow current to flow in one direction only. Transistors are electronically controlled switches that enable the functioning of modern digital computers.

Tools

Tools specifically used by electrical engineers include voltmeters, ammeters, soldering irons and oscilloscopes. Voltmeters measure the voltage, also known as the potential difference, between two points in an electrical circuit. Ammeters measure the flow of current in a circuit. Soldering irons are used to join electrical components using a molten metal. Oscilloscopes are used to detect and display signals in electrical circuits.

Formulas

There are a number of fundamental formulas used in electrical engineering. One of these is Ohm's Law. This states that for an Ohmic conductor the voltage between two points in the conductor is equal to the product of the current and the resistance. Another way of saying this is "V = IR." Another important formula is "P = IV." This means that electrical power is equal to the product of current and voltage.

The field of electrical engineering contains many neologisms and jargon, as well as familiar words used in a specific sense:

Electrical energy: is caused by moving electric charges called electrons.

Electricity: is a type of energy that comes from electrical energy.

Power stations: are where electricity is generated.

Turbines: are machines for producing continuous power. In power stations, turbines are turned using energy from sources such as heat, wind and moving water.

Alternating Current (AC): An electric current that reverses its direction many times a second at regular intervals.

Ammeter: An instrument for measuring the flow of electrical current in amperes. Ammeters are always connected in series with the circuit to be tested.

Ampere-Hour (Ah): A unit of measure for battery capacity. It is obtained by multiplying the current (in amperes) by the time (in hours) during which current flows. For example, a battery which provides 5 amperes for 20 hours is said to deliver 100 ampere - hours.

Ampere (A):A unit of measure for the intensity of an electric current flowing in a circuit. One ampere is equal to a current flow of one coulomb per second.

Apparent Power: Measured in volt-amperes (VA). Apparent power is the product of the rms (root mean square) voltage and the rms current.

Armature: The movable part of a generator or motor. It is made up of conductors which rotate through a magnetic field to provide voltage or force by electromagnetic induction. The pivoted points in generator regulators are also called armatures.

Capacitance: The ability of a body to store an electrical charge. Measured in farads as the ratio of the electric charge of the object (Q, measured in coulombs) to the voltage across the object (V, measured in volts).

Capacitor: A device used to store an electric charge, consisting of one or more pairs of conductors separated by an insulator. Commonly used for filtering out voltage spikes.

Circuit: A closed path in which electrons from a voltage or current source flow. Circuits can be in series, parallel, or in any combination of the two.

Circuit Breaker: An automatic device for stopping the flow of current in an electric circuit. To restore service, the circuit breaker must be reset (closed) after correcting the cause of the overload or failure. Circuit breakers are used in conjunction with protective relays to protect circuits from faults.

Conductor: Any material where electric current can flow freely. Conductive materials, such as metals, have a relatively low resistance. Copper and aluminum wire are the most common conductors.

Corona: A corona discharge is an electrical discharge brought on by the ionization of a fluid such as air surrounding a conductor that is electrically charged. Spontaneous corona discharges occur naturally in high-voltage systems unless care is taken to limit the electric field strength.

Current (I): The flow of an electric charge through a conductor. An electric current can be compared to the flow of water in a pipe. Measured in amperes.

Cycle: The change in an alternating electrical sine wave from zero to a positive peak to zero to a negative peak and back to zero.

Demand: The average value of power or related quantity over a specified period of time.

Dielectric constant: A quantity measuring the ability of a substance to store electrical energy in an electric field.

Dielectric strength: The maximum electric field that a pure material can withstand under ideal conditions without breaking down (i.e., without experiencing failure of its insulating properties).

Diode: A semiconductor device with two terminals, typically allowing the flow of current in one direction only. Diodes allow current to flow when the anode is positive in relation to the cathode.

Direct Current (DC): An electric current that flows in only one direction.

Electrolyte: Any substance which, in solution, is dissociated into ions and is thus made capable of conducting an electrical current. The sulfuric acid - water solution in a storage battery is an electrolyte.

Electromotive Force (EMF): A difference in potential that tends to give rise to an electric current. Measured in volts.

Electron: A tiny particle which rotates around the nucleus of an atom. It has a negative charge of electricity.

Electron theory: The theory which explains the nature of electricity and the exchange of "free" electrons between atoms of a conductor. It is also used as one theory to explain direction of current flow in a circuit.

Farad: A unit of measure for capacitance. One farad is equal to one coulomb per volt.

Ferroresonance (nonlinear resonance): a type of resonance in electric circuits which occurs when a circuit containing a nonlinear inductance is fed from a source that has series capacitance, and the circuit is subjected to a disturbance such as opening of a switch. It can cause overvoltages and overcurrents in an electrical power system and can pose a risk to transmission and distribution equipment and to operational personnel.

Frequency: The number of cycles per second. Measured in Hertz. If a current completes one cycle per second, then the frequency is 1 Hz; 60 cycles per second equals 60 Hz.

Fuse: A circuit interrupting device consisting of a strip of wire that melts and breaks an electric circuit if the current exceeds a safe level. To restore service, the fuse must be replaced using a similar fuse with the same size and rating after correcting the cause of failure.

Generator: A device which converts mechanical energy into electrical energy.

Ground: The reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.

Ground Fault Circuit Interrupters (GFCI): A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

Henry: A unit of measure for inductance. If the rate of change of current in a circuit is one ampere per second and the resulting electromotive force is one volt, then the inductance of the circuit is one Henry.

Hertz: A unit of measure for frequency. Replacing the earlier term of cycle per second (cps).

Impedance: The measure of the opposition that a circuit presents to a current when a voltage is applied. Impedance extends the concept of resistance to AC circuits, and possesses both magnitude and phase, unlike resistance, which has only magnitude.

Inductance: The property of a conductor by which a change in current flowing through it induces (creates) a voltage (electromotive force) in both the conductor itself (self-inductance) and in any nearby conductors (mutual inductance). Measured in Henry (H).

Inductor: A coil of wire wrapped around an iron core. The inductance is directly proportional to the number of turns in the coil.

Insulator: Any material where electric current does not flow freely. Isolative materials, such as glass, rubber, air, and many plastics have a relatively high resistance. Insulators protect equipment and life from electric shock.

Inverter: An apparatus that converts direct current into alternating current.

Kilowatt-hour (kWh): The product of power in kW and time in hours. Equal to 1000 Watt-hours. For example, if a 100W light bulb is used for 4 hours, 0.4kWhs of energy will be used (100W x 1kW / 1000 Watts x 4 hours). Electrical energy is sold in units of kWh.

Kilowatt-hour Meter: A device used to measure electrical energy use.

Kilowatt (kW): Equal to 1000 watts.

Load: Anything which consumes electrical energy, such as lights, transformers, heaters and electric motors.

Load Rejection: The condition in which there is a sudden load loss in the system which causes the generating equipment to be over-frequency. A load rejection test confirms that the system can withstand a sudden loss of load and return to normal operating conditions using its governor. Load banks are normally used for these tests as part of the commissioning process for electrical power systems.

Mutual Induction: Occurs when changing current in one coil induces voltage in a second coil.

Ohm (Ω): A unit of measure of resistance. One ohm is equivalent to the resistance in a circuit transmitting a current of one ampere when subjected to a potential difference of one volt.

Ohm's Law: The mathematical equation that explains the relationship between current, voltage, and resistance ($V=IR$).

Ohmmeter: An instrument for measuring the resistance in ohms of an electrical circuit.

Open Circuit: An open or open circuit occurs when a circuit is broken, such as by a broken wire or open switch, interrupting the flow of current through the circuit. It is analogous to a closed valve in a water system.

Parallel Circuit: A circuit in which there are multiple paths for electricity to flow. Each load connected in a separate path receives the full circuit voltage, and the total circuit current is equal to the sum of the individual branch currents.

Piezoelectricity: Electric polarization in a substance (especially certain crystals) resulting from the application of mechanical stress (pressure).

Polarity: A collective term applied to the positive (+) and negative (-) ends of a magnet or electrical mechanism such as a coil or battery.

Power: The rate at which electrical energy is transferred by an electric circuit. Measured in Watts.

Power Factor: The ratio of the actual electrical power dissipated by an AC circuit to the product of the rms. values of current and voltage. The difference between the two is caused by reactance in the circuit and represents power that does no useful work.

Protective Relay: A relay device designed to trip a circuit breaker when a fault is detected.

Reactive Power: The portion of electricity that establishes and sustains the electric and magnetic fields of AC equipment. Exists in an AC circuit when the current and voltage are not in phase. Measured in VARS.

Rectifier: An electrical device that converts an alternating current into a direct one by allowing a current to flow through it in one direction only.

Relay: An electrical coil switch that uses a small current to control a much larger current.

Reluctance: The resistance that a magnetic circuit offers to lines of force in a magnetic field.

Resistance: The opposition to the passage of an electric current. Electrical resistance can be compared to the friction experienced by water when flowing through a pipe. Measured in ohms.

Resistor: A device usually made of wire or carbon which presents a resistance to current flow.

Rotor: The rotating part of an electrical machine such as a generator, motor, or alternator.

Self Induction: Voltage which occurs in a coil when there is a change of current.

Semiconductor: A solid substance that has conductivity between that of an insulator and that of most metals, either due to the addition of an impurity or because of temperature effects. Devices made of semiconductors, notably silicon, are essential components of most electronic circuits.

Series-Parallel Circuit: A circuit in which some of the circuit components are connected in series and others are connected in parallel.

Series Circuit: A circuit in which there is only one path for electricity to flow. All of the current in the circuit must flow through all of the loads.

Service: The conductors and equipment used to deliver energy from the electrical supply system to the system being served.

Short Circuit: When one part of an electric circuit comes in contact with another part of the same circuit, diverting the flow of current from its desired path.

Solid State Circuit: Electronic (integrated) circuits which utilize semiconductor devices such as transistors, diodes and silicon controlled rectifiers.

Transistor: A semiconductor device with three connections, capable of amplification in addition to rectification.

True Power: Measured in Watts. The power manifested in tangible form such as electromagnetic radiation, acoustic waves, or mechanical phenomena. In a direct current (DC) circuit, or in an alternating current (AC) circuit whose impedance is a pure resistance, the voltage and current are in phase.

VARS: A unit of measure of reactive power. Vars may be considered as either the imaginary part of apparent power, or the power flowing into a reactive load, where voltage and current are specified in volts and amperes.

Variable Resistor: A resistor that can be adjusted to different ranges of value.

Volt-Ampere (VA): A unit of measure of apparent power. It is the product of the rms voltage and the rms current.

Volt (V): A unit measure of voltage. One volt is equal to the difference of potential that would drive one ampere of current against one ohm resistance.

Voltage: An electromotive force or "pressure" that causes electrons to flow and can be compared to water pressure which causes water to flow in a pipe. Measured in volts.

Voltmeter: An instrument for measuring the force in volts of an electrical current. This is the difference of potential (voltage) between different points in an electrical circuit. Voltmeters have a high internal resistance are connected across (parallel to) the points where voltage is to be measured.

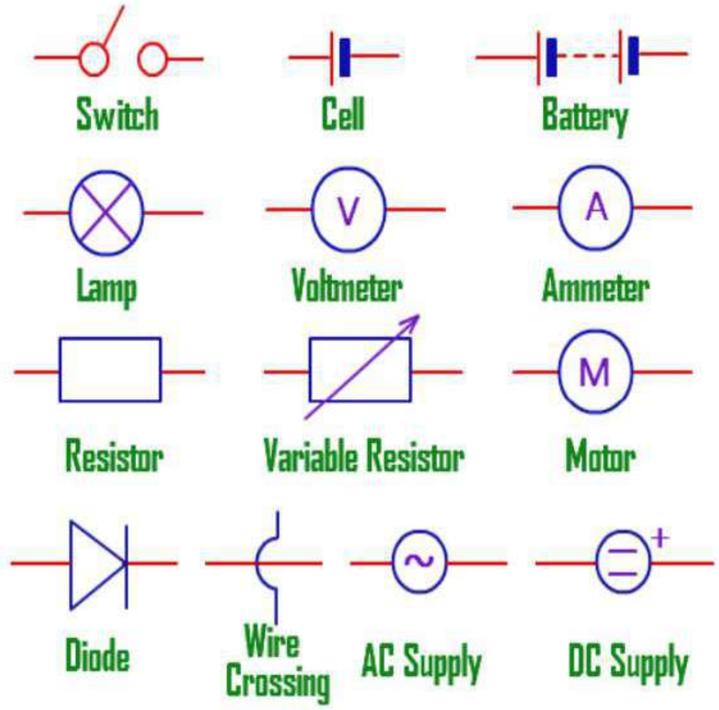
Watt-hour (Wh): A unit of electrical energy equivalent to a power consumption of one watt for one hour.

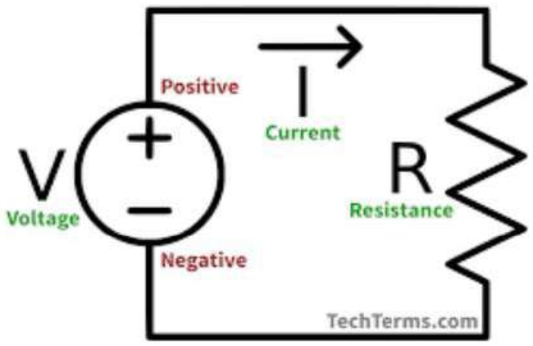
Watt (W): A unit of electrical power. One watt is equivalent to one joule per second, corresponding to the power in an electric circuit in which the potential difference is one volt and the current one ampere.

Wattmeter: The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit.

Waveform: A graphical representation of electrical cycles which shows the amount of variation in amplitude over some period of time.

Basic electrical circuit elements:





PART TWO

ELECTRICAL ENGINEERING

1- History

Francisco Salva Campillo

William Gilbert

Thomas·Edison¶

William Sturgeo

Johan Wilcke

It is needless to mention that how much we are dependent on electricity in our day to day life. Electricity has been a subject of scientific interest since at least the early 17th century. William Gilbert was a prominent early electrical scientist, and was the first to draw a clear distinction between magnetism and static electricity. He is credited with establishing the term "electricity". He also designed the versorium which a device that detects the presence of statically charged objects. In 1762 Swedish professor Johan Wilcke invented a device later named electrophorus that produced a static electric charge. By 1800 Alessandro Volta had developed the voltaic pile, a forerunner of the electric battery. In the 19th century, research into the subject started to intensify. Notable developments in this century including the work of many scientists and inventors such as: Hans Christian Ørsted, n, Edward Davy, Georg Ohm and …etc.

Furthermore, electrical engineering is the driver behind the world's buildings and infrastructure that we all use each and every day. During the 19th century use of electrical engineering increased dramatically where Thomas Edison switched on the world's first large-scale electric power network that provided 110 volts direct current (DC. In 1884, Sir Charles Parsons invented the turbine allowing for more efficient electric power generation. Alternating current, with its ability to transmit power more efficiently over long distances via the use of transformers, developed rapidly later on with transformer designs by ZBD transformers, Lucien Gaulard, John Dixon Gibbs and William Stanley, Jr.. Practical AC motor designs including induction motors were independently invented by Galileo Ferraris and Nikola Tesla and further developed into a practical three-phase form by Mikhail Dolivo-Dobrovolsky and Charles Eugene Lancelot Brown. Charles Steinmetz and Oliver Heaviside contributed to the theoretical basis of alternating current engineering.

2- Definition

Electrical engineering is a professional engineering discipline that generally deals with the study and application of electricity, electronics, and electromagnetism. This field first became an identifiable occupation in the later half of the 19th century after commercialization of the electric telegraph, the telephone, and electric power distribution and use. Subsequently, broadcasting and recording media made electronics part of daily life. The invention of the transistor, and later the integrated circuit, brought down the cost of electronics to the point they can be used in almost any household object.

3- Subfields

Electrical engineering has now subdivided into a wide range of subfields including electronics, digital computers, computer engineering, power engineering, telecommunications, control systems, robotics, radio-frequency engineering, signal processing, instrumentation, and microelectronics. Many of these subdisciplines overlap with other engineering branches, spanning a huge number of specializations such as hardware engineering, power electronics, electromagnetics & waves, microwave engineering, nanotechnology, electrochemistry, renewable energies, mechatronics, electrical materials science, and much more.

Power : Power engineering :deals with the **generation**, **transmission**, and **distribution** of **electricity** as well as the design of a range of related devices. These include **transformers**, **electric generators**, **electric motors**, high voltage engineering, and **power electronics**.

Electronics : Electronic engineering involves the design and testing of **electronic circuits** that use the properties of **components** such as **resistors**, **capacitors**, **inductors**, **diodes**, and **transistors** to achieve a particular functionality. The **tuned circuit** allows the user of a **radio** to **filter** out all but a single station.

Microelectronics: **Microelectronics** engineering deals with the design and **microfabrication** of very small electronic circuit components for use in an **integrated circuit** or sometimes for use on their own as a general electronic component.

Nanoelectronics: is the further scaling of devices down to **nanometer** levels

Signal processing : deals with the analysis and manipulation of **signals**.Signals can be either **analog**, or **digital**. For analog signals, signal processing may involve the **amplification** and **filtering** of audio signals for audio equipment or the **modulation** and **demodulation** of signals for **telecommunications**. For digital signals, signal processing may involve the **compression**, **error detection** and **error correction** of digitally sampled signals.

4- Role of an Electrical Engineer

Electrical engineers **design, develop, and test electrical devices and equipment**, including communications systems, power generators, motors and navigation systems, and electrical systems for automobiles and aircraft. They also oversee the **manufacture of these devices, systems, and equipment.** In order to effectively perform their jobs, Electrical Engineers are accountable for the design, maintenance, implementation and/or improvement of electrical instruments, facilities, components, equipment products, or systems for industrial, commercial or domestic purposes. They make use of a wide range of computer-assisted design or engineering software and equipment in order to this. Apart from the technical side of their role, electrical engineers also confer with customers, engineers, and others to discuss existing or potential engineering products or projects.

5- Responsibilities of an Electrical Engineer

- Electrical Engineers are responsible for ensuring installation and operations of electrical aspects conform to standards and customer requirements by preparing electrical systems specifications, technical drawings or topographical maps.

- Establishing construction, manufacturing or installation standards or specifications by performing a wide range of detailed calculations.
- Writing reports and compiling data regarding existing and potential electrical engineering projects and studies.
- Planning and realization of projects
- Measurement and evaluation of electronic processes
- Execution of tests and experiments
- Supervising or training project team members.
- Working with a variety of technicians.

6- Skills Required

- Circuit designing – Debug, synthesize, and analyze electrical circuits.
- Knowledge of software such as Orcad, P Spice, and Eagle.
- Ability to use instrumentation and take electrical measurements
- Testing, reading, construction, and design of electrical machinery.
- Designing and fabricating power electronic circuits.
- Knowledge of micro-controllers such as 8051, ARM, AVR, PIC.

PART THREE

ELECTRICAL ENGINEERING FIELDS

I- INDUSTRIAL ELECTRICAL ENGINEERING

1- Definition:

Electrical engineering refers to the analysis, design, manufacture and maintenance of equipment and products based on the combination of electrical/electronic circuits and mechanical systems used in the industry.

Industrial engineering is an engineering profession that is concerned with the optimization of complex processes, systems, or organizations by developing, improving and implementing integrated systems. The industrial processes are especially prominent in systems such as those of DC or AC rotating electrical machines which can be designed and operated to generate power from a mechanical process (generator) or used to power a mechanical effect (motor).

Industrial engineers use specialized knowledge and skills in the mathematical and physical, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results obtained from systems and processes. From these results, they are able to create new systems, processes or situations for the useful coordination of labor, materials and machines and also improve the quality and productivity of systems.

2- The Engineering Technology

It provides a solid technical base in engineering science fundamentals and provides competency in automation, controls, motion mechanics, solid mechanics, fluid power, electrical systems, electronics and computer integrated systems.

3- Tasks of Electrical engineers

They design and develop equipment and machinery that use both electrical and mechanical technology. They make draughts and prepare documents detailing the material requisitions, the assembly process and other technical specifications.

4- Electrical systems

They have roots in the silicon revolution, which can be traced back to two important silicon semiconductor inventions from 1959: the monolithic integrated circuit (IC) chip by Robert Noyce at Fairchild Semiconductor, and the MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor, or MOS Transistor) by Mohamed M. Atalla and Dawon Kahng at Bell Labs. MOSFET scaling, the miniaturization of MOSFETs on IC chips, led to the miniaturization of electronics. This laid the foundations for the miniaturisation of mechanical systems, with the development of micromachining technology based on silicon semiconductor devices, as engineers began realizing that silicon chips and MOSFETs could interact and communicate with the surroundings and process things such as chemicals, motions and light. One of the first silicon pressure sensors was isotropically micromachined by Honeywell in 1962.

An early example of such devices is the resonant-gate transistor, an adaptation of the MOSFET, developed by Harvey C. Nathanson in 1965. During the 1970s to early 1980s, a number of MOSFET microsensors were developed for measuring physical, chemical, biological and environmental parameters. In the early 21st century, there has been research on nanoelectromechanical systems (NEMS).

5- Modern electrical processes

Today, modern electrical processes are mainly used by power companies. All fuel based generators convert mechanical movement to electrical power. Some renewable energies such as wind and hydroelectric are powered by mechanical systems that also convert movement to electricity.

In the last thirty years of the 20th century, equipment which would generally have used electromechanical devices became less expensive. This equipment became cheaper because it used more reliably integrated microcontroller circuits containing ultimately a few million transistors, and a program to carry out the same task through logic. With electromechanical components there were only moving parts, such as mechanical electric actuators. This more reliable logic has replaced most electromechanical devices, because any point in a system which must rely on mechanical movement for proper operation will inevitably have mechanical wear and eventually fail. Properly designed electronic circuits without moving parts will continue to operate correctly almost indefinitely and are used in most simple feedback control systems. Circuits without moving parts appear in a large number of items from traffic lights to electronic boards of washing machines.

II- ELECTROMECHANICAL ENGINEERING

6- Definition:

Electromechanical engineering refers to the analysis, design, manufacture and maintenance of equipment and products based on the combination of electrical/electronic circuits and mechanical systems.

In engineering, electromechanics combines processes and procedures drawn from electrical engineering and mechanical engineering. Electromechanics focuses on the interaction of electrical and mechanical systems as a whole and how the two systems interact with each other. This process is especially prominent in systems such as those of DC or AC rotating electrical machines which can be designed and operated to generate power from a mechanical process (generator) or used to power a mechanical effect (motor). Electrical engineering in this context also encompasses electronics engineering.

7- The Electromechanical Engineering Technology

It provides a solid technical base in engineering science fundamentals and provides competency in automation, controls, motion mechanics, solid mechanics, fluid power, electrical systems, electronics and computer integrated systems.

8- Electromechanical devices

They are ones which have both electrical and mechanical processes. Strictly speaking, a manually operated switch is an electromechanical component due to the mechanical movement causing an electrical output. Though this is true, the term is usually understood to refer to devices which involve an electrical signal to create mechanical movement, or vice versa mechanical movement to create an electric signal. Often involving electromagnetic principles such as in relays, which allow a voltage or current to control another, usually isolated circuit voltage or current by mechanically switching sets of contacts, and solenoids, by which a voltage can actuate a moving linkage as in solenoid valves.

9- Tasks of Electromechanical engineers

They design and develop equipment and machinery that use both electrical and mechanical technology. They make draughts and prepare documents detailing the material requisitions, the assembly process and other technical specifications.

10-Microelectromechanical systems (MEMS)

Microelectromechanical systems (MEMS) have roots in the silicon revolution, which can be traced back to two important silicon semiconductor inventions from 1959: the monolithic integrated circuit (IC) chip by Robert Noyce at Fairchild Semiconductor, and the MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor, or MOS Transistor) by Mohamed M. Atalla and Dawon Kahng at Bell Labs. MOSFET scaling, the miniaturization of MOSFETs on IC chips, led to the miniaturization of electronics. This laid the foundations for the miniaturisation of mechanical systems, with the development of micromachining technology based on silicon semiconductor devices, as engineers began realizing that silicon chips and MOSFETs could interact and communicate with the surroundings and process things such as chemicals, motions and light. One of the first silicon pressure sensors was isotropically micromachined by Honeywell in 1962.

An early example of a MEMS device is the resonant-gate transistor, an adaptation of the MOSFET, developed by Harvey C. Nathanson in 1965. During the 1970s to early 1980s, a number of MOSFET microsensors were developed for measuring physical, chemical, biological and environmental parameters. In the early 21st century, there has been research on nanoelectromechanical systems (NEMS).

11-Modern electromechanical processes

Today, electromechanical processes are mainly used by power companies. All fuel based generators convert mechanical movement to electrical power. Some renewable energies such as wind and hydroelectric are powered by mechanical systems that also convert movement to electricity.

In the last thirty years of the 20th century, equipment which would generally have used electromechanical devices became less expensive. This equipment became cheaper because it used more reliably integrated microcontroller circuits containing ultimately a few million transistors, and a program to carry out the same task through logic. With electromechanical components there were only moving parts, such as mechanical electric actuators. This more reliable logic has replaced most electromechanical devices, because any point in a system which must rely on mechanical movement for proper operation will inevitably have mechanical wear and eventually fail. Properly designed electronic circuits without moving parts will continue to operate correctly almost indefinitely and are used in most simple feedback control systems. Circuits without moving parts appear in a large number of items from traffic lights to washing machines.

Another electromechanical device is piezoelectric devices, but they do not use electromagnetic principles. Piezoelectric devices can create sound or vibration from an electrical signal or create an electrical signal from sound or mechanical vibration.

1- Friction

Friction in machines is destructive and wasteful. It causes the moving parts to wear and it produces heat where it is not wanted. Engineers reduce friction by using very highly polished materials and by lubricating their surfaces with oil and grease. They also use ball bearings and roller bearings because rolling objects cause less friction than sliding ones.

III- RENEWABLE ENERGY

phones to water heaters, from electric cars to the frozen food aisle at the grocery store, electric power and electronic devices undergird every facet of our civilization. In addition the development of systems implementing renewable energy sources is essential to society's evolution and survival. Currently the major source for electric energy is the burning of fossil fuels; thus, it is a problem because of two reasons: it increases the emission of harmful gases to our atmosphere and it is an energy source that will not last forever. In our present time the amount of energy produced by a single renewable source is considerably smaller that the amount produced by the burning of fossil fuels. Therefore, it is necessary to develop energy systems that will use various type of renewable energy in parallel, all contributing to a large complex system. For this reason, the role of an electrical engineer in society is significant.

2-Definition

Renewable energy sources are becoming increasingly important. Verbruggen defined Renewable energy as "any form of energy from solar, geophysical, or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use". In a broad sense, the term renewable energy refers to biomass energy, hydro energy, solar energy, wind energy, geothermal energy, and ocean energy (tidal, wave, current, ocean thermal and osmotic energy). In the literature the term "new renewable" is also used, referring to modern technologies and approaches to convert energy from renewable sources to energy carriers people can use, taking into account sustainability requirements. In general, "new renewable" includes modern biomass energy conversion technologies, geothermal heat and electricity production, smaller-scale use of hydropower, low and high-temperature heat production from solar energy, wind conversion machines (wind turbines), solar photovoltaic and solar thermal electricity production, and the use of ocean energy (UNDP et al., 2000 ; REN21, 2005 ; Johansson et al., 2006).

3- Renewable energy sources

Renewable energies include all energy sources that do not come from finite resources. Renewable energy sources, also called renewables, are energy sources that replenish (or renew) themselves naturally. Typical examples are solar energy, wind and biomass.

Renewable energy sources in energy statistics include the following:

Non-combustible renewables:

Hydropower: the electricity generated from the potential and kinetic energy of water in hydroelectric plants (the electricity generated in pumped storage plants is not included), Tide, wave, ocean energy: mechanical energy derived from tidal movement, wave motion or ocean current and exploited for electricity generation.

Geothermal energy: the energy available as heat from within the earth's crust, usually in the form of hot water or steam.

Wind energy: the kinetic energy of wind converted into electricity in wind turbines.

Solar energy: solar thermal energy (radiation exploited for solar heat) and solar photo-voltaic for electricity production.

Ambient heat (heat pumps): heat pumps that are driven by electricity or other supplementary energy, to extract (stored) energy from the air, the ground or the water and converts/transfers this into energy to be used elsewhere (e.g. to heat space via under floor heating systems and/or water in domestic buildings). Heat pumps can be used by individual households as well as at larger scale in industry and in commercial and public services. Energy flows related to heat pumps used for cooling are excluded, only heat pumps used for heating (hot water) are included.

Combustible renewables:

Biofuels**:** fuels from *biomass*; includes solid biofuels, biogas and liquid biofuels

4- Exercises

a) What are the typical efficiencies of monocrystalline, polycrystalline silicon cells, and non-silicon cells?

Polycrystalline Solar Panels: Under standard conditions their conversion efficiency of sunlight to electricity is 12% to 12.5%,

Monocrystalline Solar Panels: Under standard conditions their conversion efficiency of sunlight to electricity is 12% to 15%,

Amorphous modules: Their conversion efficiency of sunlight to electricity is 6.3%, about half that of polycrystalline or monocrystalline panels.

Thin films GaAs. Their conversion efficiency of sunlight to electricity is 30-40%.

Thin films CIGS: Their conversion efficiency of sunlight to electricity is 20%.

Thin films CdTe: Their conversion efficiency of sunlight to electricity is 15%

b) Imagine a family living in Africa. They have no grid connection and hence no electricity so they intend to buy a Solar Home System (SHS). This will allow them to have light and to watch TV in the evening. You must help them to look at their electricity requirement to see what size of SHS will provide enough electricity.

In Africa, where their home is, the energy from the sun averages 6 kWh/m2 each day. That means the energy provided from the sun is equivalent to a light intensity of 1000W/m2 for six hours each day. In fact there would be about 12 hours of sunlight during which time the light intensity would vary but the daily total would be 6 kWh/m^2

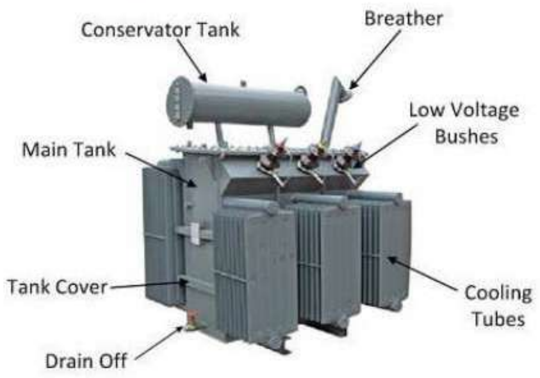
- The PV module in a SHS has a power output of 50 Wp. Assuming that the module operates at 25°C (i.e. at STC), how much electricity will it provide every day?
- The family wants to have one light in the main room of the house, one light in the kitchen and one on a table where the children do their homework. Of course they would use low energy light bulbs, which require between seven and twenty Watts.
  (Equivalence of low energy light bulbs to standard light bulbs: 7 W @ 40 W, 11 W @ 60 W, 16 W @ 75 W & 20 W @ 100 W).

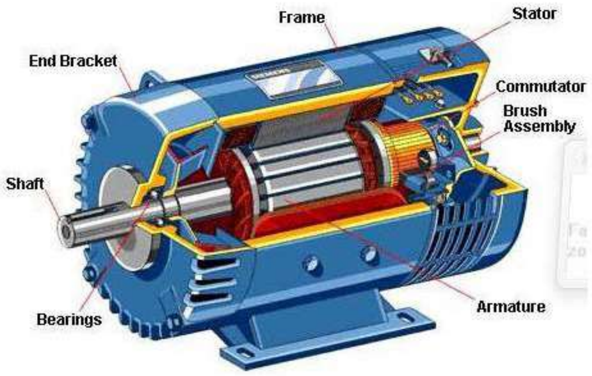
Which light bulbs would it be best to use for the different lamps and why?

- Assume that the main light is used for four hours a day, the kitchen light for two hours per day and the table light for three hours each day. How much electrical energy does each light use each and what is the total daily requirement of the lights? What power output would a PV module require to supply this electricity?
- The family also likes to watch TV. If their television requires 50 W and they watch every day for two hours, what is its daily electrical energy requirement?
- Does the PV module in the SHS supply enough energy for all their needs?
- Discuss the result.

Reference: http://staff.fit.ac.cy/eng.ap/SPRING2019/AEEE522/SolutionPVExercisesUnsecured.pdf

IV- ELECTRICAL MACHINES





1- Description of Rotating Electric Machines and Transformers

An electric machine is a device that performs energy conversion from mechanical to electrical energy. When this device is applied for mechanical to electrical energy conversion, it becomes a generator. But when the energy conversion is from electrical energy to mechanical energy, it is referred to as a motor. Through magnetic field action, virtually every motor and generator perform energy conversion from one form to another. This section will focus on conversion processes based on the utilization of magnetic fields.

Another closely related device is the transformer. Any device that converts electric energy from one voltage level to another is termed a transformer. Since similar principles guides them as that of generators and motors they are all grouped together, based on the magnetic field to initiate the voltage change. These three electric devices find application in modern day life. Electric motors are used as drive in blenders, fans, vacuum cleaners, refrigerators, air-conditioners, freezers and many similar appliances. In the workplace, they provide motive power for virtually all tools. Additionally, the power supply to run these motors are provided by generators

Why are electric motors and generators so common? The answer is quite simple. Electric power is clean and an energy source that is efficient. The fact that less ventilation and fuel is required in an electric motor than in an internal combustion engine, it therefore becomes more suitable for use in environments where combustion pollution is undesired. Thus, in such situations, energy conversion from mechanical or heat energy (involving combustion) to electrical energy at a distant location and subsequently transmitted to the homes, factories or offices via electric cables as clean energy. Transformers are important in this process because they ensure energy loss reduction that normally arises between the power generation source and the point of utilization. The history of this device is this:

Electrical machines theory is one of the recent branches of human knowledge. The design and construction of electrical machines is dated back to the ending of 19th century. In the early part of the 20th century, electricity had already gone deep into industries and living homes. During this development period, electrical machines have performed tremendously in electrical engineering field. The physical phenomena, magnetism and electricity, are the basis of modern electrical engineering.. For this reason, electrical machines are electromagnetic system, made up of a magnetic circuit and electric circuit coupled together. The magnetic circuit consists of a stationary and rotating member and non magnetic airgap, which separate the two. Rotating electrical machines greatly vary in size, from few watts to over 1000 kW.

Reference: Ibe O. Anthony and Uhunmwangho Roland, 2017 Ibe A.O. and Uhunmwangho Roland. “Introduction to Electrical Engineering, Second Edition” Odus Press, Enugu, Nigeria, 2017. ISBN: 978-36289-7-6 143

2- Exercises

a) A variable-speed drive system uses a dc motor which is supplied from a variable voltage source. The drive speed is varied from 0 to 1500 rpm (base speed) by varying the terminal voltage from 0 to 500 V (rated value) with the field current maintained constant. The speed beyond (above) the base speed is obtained by field weakening while the armature voltage is held constant at 500 V (rated value). The rated value of the torque below 1500 rpm (base speed) is 300 Nm.

Armature reaction, iron losses and the voltage drop over the armature resistance may be neglected.

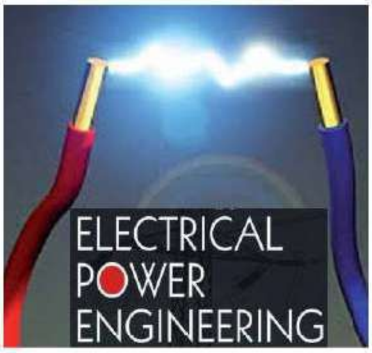
- Determine the motor armature current if the torque is held constant at the rated value of 300 Nm below 1500 rpm (base speed).
- Determine the torque available at a speed of 3000 rpm if the armature current is held constant at the value obtained in question b.

b) A three-phase, 500 MVA 20.8 kV four-pole star-connected synchronous machine has negligible stator resistance and a synchronous reactance of 0.8 Ohm per phase at rated terminal voltage. The machine is operated as a generator connected to a three-phase 20.8 kV infinite bus. Note: 20.8 kV is the line voltage.

- Give the per-phase equivalent circuit of the synchronous machine.
- Calculate the phase voltage.
- Sketch the phasor diagram when the machine is delivering rated MVA at a power factor of 0.8 lagging.
- Determine the excitation voltage and the power angle when the machine is delivering rated MVA at a power factor of 0.8 lagging

Reference: https://ocw.tudelft.nl/wp-content/uploads/ET4117_Exam_Nov_2003.pdf

V- ELECTRICAL POWER ENGINEERING



1- Definition of Power Engineering

It is 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. It copes with the design of a range of related devices. These include transformers, electric generators, electric motors and power electronics. Although much of the field is concerned with the problems of three-phase AC power – the standard for large-scale power transmission and distribution across the modern world – a significant fraction of the field is concerned with the conversion between AC and DC power and the development of specialized power systems such as those used in aircraft or for electric railway networks. Power engineering draws the majority of its theoretical base from electrical engineering.

2- History

In 1881 two electricians built the world's first power station in England. The station employed two waterwheels to produce an alternating current that was used to supply seven Siemens arc lamps at 250 volts and thirty-four incandescent lamps at 40 volts. However supply was intermittent and in 1882 Thomas Edison and his company, The Edison Electric Light Company, developed the first steam-powered electric power station on Pearl Street in New York City. The Pearl Street Station consisted of several generators and initially powered around 3,000 lamps for 59 customers. The power station used direct current and operated at a single voltage. Since the direct current power could not be easily transformed to the higher voltages necessary to minimise power loss during transmission, the possible distance between the generators and load was limited to around half-a-mile (800 m).

That same year in London Lucien Gaulard and John Dixon Gibbs demonstrated the first transformer suitable for use in a real power system. The practical value of Gaulard and Gibbs' transformer was demonstrated in 1884 at Turin where the transformer was used to light up forty kilometres (25 miles) of railway from a single alternating current generator. Despite the success of the system, the pair made some fundamental mistakes. Perhaps the most serious was connecting the primaries of the transformers in series so that switching one lamp on or off would affect other lamps further down the line. Following the demonstration George Westinghouse, an American entrepreneur, imported a number of the transformers along with a Siemens generator and set his engineers to experimenting with them in the hopes of improving them for use in a commercial power system.

One of Westinghouse's engineers, William Stanley, recognised the problem with connecting transformers in series as opposed to parallel and also realised that making the iron core of a transformer a fully enclosed loop would improve the voltage regulation of the secondary winding. Using this knowledge he built the world's first practical transformer based alternating current power system at Great Barrington, Massachusetts in 1886. In 1885 the Italian physicist and electrical engineer Galileo Ferraris demonstrated an induction motor and in 1887 and 1888 the Serbian-American engineer Nikola Tesla filed a range of patents related to power systems including one for a practical two-phase induction motor which Westinghouse licensed for his AC system.

By 1890 the power industry had flourished and power companies had built thousands of power systems (both direct and alternating current) in the United States and Europe – these networks were effectively dedicated to providing electric lighting. During this time a fierce rivalry in the US known as the "war of the currents" emerged between Edison and Westinghouse over which form of transmission (direct or alternating current) was superior. In 1891, Westinghouse installed the first major power system that was designed to drive an electric motor and not just provide electric lighting. The installation powered a 100 horsepower (75 kW) synchronous motor at Telluride, Colorado with the motor being started by a Tesla induction motor. On the other side of the Atlantic, Oskar von Miller built a 20 kV 176 km three-phase transmission line from Lauffen am Neckar to Frankfurt am Main for the Electrical Engineering Exhibition in Frankfurt. In 1895, after a protracted decision-making process, the Adams No. 1 generating station at Niagara Falls began transmitting three-phase alternating current power to Buffalo at 11 kV. Following completion of the Niagara Falls project, new power systems increasingly chose alternating current as opposed to direct current for electrical transmission.

3- Fields of Power Engineering

Electricity generation covers the selection, design and construction of facilities that convert energy from primary forms to electric power.

Electric power transmission requires the engineering of high voltage transmission lines and substation facilities to interface to generation and distribution systems. High voltage direct current systems are one of the elements of an electric power grid.

Electric power distribution engineering covers those elements of a power system from a substation to the end customer.

Power system protection is the study of the ways an electrical power system can fail, and the methods to detect and mitigate for such failures.

In most projects, a power engineer must coordinate with many other disciplines such as civil and mechanical engineers, environmental experts, and legal and financial personnel. Major power system projects such as a large generating station may require scores of design professionals in addition to the power system engineers. At most levels of professional power system engineering practice, the engineer will require as much in the way of administrative and organizational skills as electrical engineering knowledge.

4- Off-grid power systems

Power engineers may also work on systems that do not connect to the grid. These systems are called off-grid power systems and may be used in preference to on-grid systems for a variety of reasons. For example, in remote locations it may be cheaper for a mine to generate its own power rather than pay for connection to the grid and in most mobile applications connection to the grid is simply not practical.

5- Smart grid

A smart grid is an electricity network enabling a two-way flow of electricity and data with digital communications technology enabling to detect, react and pro-act to changes in usage and multiple issues. Smart grids have self-healing capabilities and enable electricity customers to become active participants.

A smart grid is a holistic solution that employs a broad range of information technology resources, allowing existing and new gridlines to reduce electricity waste and energy costs.

A smart grid is an electricity network that uses digital and other advanced technologies. to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users.

The advantages of smart grids are :

1. The definitive solution for managing the grids of the future.
2. Energy savings through reducing consumption. ...
3. Better customer service and more accurate bills. ...
4. Fraud detection and technical losses. ...
5. Increased competition. ...

PART FOUR

TENSES EXPLANATIONS

When should I use the Present Simple?

Present Uses

1: We use the present simple when something is generally or always true.
- People need food. • It snows in winter here. • Two and two make four.

2: Similarly, we need to use this tense for a situation that we think is more or less permanent. (See the present continuous for temporary situations)
- Where do you live? • She works in a bank. • I don't like mushrooms.

3: The next use is for habits or things that we do regularly. We often use adverbs of frequency (such as 'often', 'always' and 'sometimes') in this case, as well as expressions like 'every Sunday' or 'twice a month'. (See the present continuous for new, temporary or annoying habits).
- Do you smoke? • I play tennis every Tuesday. • I don't travel very often.

4: We can also use the present simple for short actions that are happening now. The actions are so short that they are finished almost as soon as you've said the sentence. This is often used with sports commentary.
- He takes the ball, he runs down the wing, and he scores!

Future Uses

5: We use the present simple to talk about the future when we are discussing a timetable or a fixed plan. Usually, the timetable is fixed by an organisation, not by us.
- School begins at nine tomorrow. • What time does the film start?
- The plane doesn't arrive at seven, it arrives at seven thirty.

6: We also use the present simple to talk about the future after words like ' 'when', 'until', 'after', 'before' and 'as soon as'. These are sometimes called subordinate clauses of time.
- I will call you when I have time. (Not 'will have'.) • I won't go out until it stops raining.
- I'm going to make dinner after I watch the news.

Conditional Uses

7: We use the present simple in the first and the zero conditionals. (See the conditionals section for more information.)
- If it rains, we won't come. • If you heat water to 100 degrees, it boils.

When should I use the Present Continuous?

Present Uses

1: First, we use the present continuous for things that are happening at the moment of speaking. These things usually last for quite a short time and they are not finished when we are talking about them.
- I'm working at the moment. • Julie is sleeping. • Please call back as we are eating dinner now.

2: We can also use this tense for other kinds of temporary situations, even if the action isn't happening at this moment.
- John's working in a bar until he finds a job in his field. (He might not be working now.)
- I'm reading a really great book. • She's staying with her friend for a week.

Compare this with the present simple, which is used for permanent situations that we feel will continue for a long time.
- I work in a school. (I think this is a permanent situation).
- I'm working in a school. (I think this is a temporary situation.)

3: We can use the present continuous for temporary or new habits (for normal habits that continue for a long time, we use the present simple). We often use this with expressions like 'these days' or 'at the moment'.
- He's eating a lot these days. • You're smoking too much
- She's swimming every morning (she didn't use to do this).

4: Another present continuous use is for habits that are not regular, but that happen very often. In this case we usually use an adverb like 'always', 'forever' or 'constantly'. Often, we use the present continuous in this way to talk about an annoying habit.
- You're forever losing your keys! • She's constantly missing the train. • Lucy's always smiling!

Future Uses

5: The next use is for definite future arrangements (with a future time word). In this case we have already made a plan and we are pretty sure that the event will happen in the future.
- I'm meeting my father tomorrow. • We're going to the beach at the weekend. • I'm leaving at three.

We can't use this tense (or any other continuous tense) with stative verbs

When should we use the Present Perfect Simple?

Unfinished Actions

1: We use this tense when we want to talk about unfinished actions or states or habits that started in the past and continue to the present. Usually we use it to say 'how long' and we need 'since' or 'for'. We often use stative verbs.
- I've known Karen since 1994. • She's lived in London for three years. • I've worked here for six months.

'Since' and 'For'

We use 'since' with a fixed time in the past (2004, April 23rd, last year, two hours ago). The fixed time can be another action, which is in the past simple (since I was at school, since I arrived).

- I've known Sam since 1992. • I've liked chocolate since I was a child. • She's been here since 2pm.

We use 'for' with a period of time (2 hours, three years, six months).

- I've known Julie for ten years. • I've been hungry for hours. • She's had a cold for a week.

Finished Actions

2: Life experience. These are actions or events that happened sometime during a person's life. We don't say when the experience happened, and the person needs to be alive now.

We often use the words 'ever' and 'never' here.

- I have been to Tokyo. • They have visited Paris three times. • We have never seen that film.

3: With an unfinished time word (this month, this week, today). The period of time is still continuing.

- I haven't seen her this month. • I've already moved house twice this year!
- She's drunk three cups of coffee today

We CAN'T use the present perfect with a finished time word.: • I've seen him yesterday.

4: A finished action with a result in the present (focus on result). We often use the present perfect to talk about something that happened in the recent past, but that is still true or important now. Sometimes we can use the past simple here, especially in US English.

- I've lost my keys (so I can't get into my house). • She's hurt her leg (so she can't play tennis today).
- They've missed the bus (so they will be late).

5: We can also use the present perfect to talk about something that happened recently, even if there isn't a clear result in the present. This is common when we want to introduce news and we often use the words 'just / yet / already / recently'. However, the past simple is also correct in these cases, especially in US English.

- The Queen has given a speech. • I've just seen Lucy.
- The Mayor has announced a new plan for the railways.

Been and Gone

In this tense, we use both 'been' and 'gone' as the past participle of 'go', but in slightly different circumstances.

We use 'been' (often when we talk about life experience) to mean that the person we're talking about visited the place and came back.

- I've been to Paris (in my life, but now I'm in London, where I live).
- She has been to school today (but now she's back at home).
- They have never been to California.

We use 'gone' (often when we are talking about an action with a result in the present) to mean that the person went to the place and is at the place now.

- 'Where's John?' 'He's gone to the shops' (he's at the shops now).
- Julie has gone to Mexico (now she's in Mexico). • They've gone to Japan for three weeks (now they're in Japan).

When should we use the Present Perfect Continuous?

Unfinished actions

1: To say how long for unfinished actions which started in the past and continue to the present. We often use this with 'for' and 'since'.

- I've been living in London for two years. • She's been working here since 2004.
- We've been waiting for the bus for hours.

This use is very similar to how we use the present perfect simple, and often it's possible to use either tense. Of course, with stative verbs, we can't use the present perfect continuous

- I've been here for hours. • NOT: I've been being here for hours.

2: For temporary habits or situations. The action started in the past and continues to the present in the same way as with use number 1, but we don't answer the questions about 'how long' so clearly. Instead, we use a word like 'recently'.

- I've been going to the gym a lot recently. • I've been reading a lot recently.
- They've been living with his mother while they look for a house.

This is very similar to the use of the present continuous for temporary habits and often either tense is possible.

Finished actions

3: Actions which have recently stopped (though the whole action can be unfinished) and have a result, which we can often see, hear, or feel, in the present. We don't use a time word here.

- I'm so tired, I've been studying. • I've been running, so I'm really hot. • It's been raining so the pavement is wet

The present perfect simple has a very similar use, which focuses on the result of the action, whereas the present perfect continuous focuses on the action itself. See my page about the difference between the present perfect simple and the present perfect continuous for more explanation.

When should we use the Past Simple?

This is the basic past tense. We use it whenever we want to talk about the past and we don't have any special situation that means we should use the past perfect, present perfect, past continuous, etc.

Finished actions, states or habits in the past.

1: We use it with finished actions, states or habits in the past when we have a finished time word (yesterday, last week, at 2 o'clock, in 2003).

- I went to the cinema yesterday.
- We spent a lot of time Japan in 2007.

2: We use it with finished actions, states or habits in the past when we know from general knowledge that the time period has finished. This includes when the person we are talking about is dead.

- Leonardo painted the Mona Lisa.
- The Vikings invaded Britain.

3: We use it with finished actions, states or habits in the past that we have introduced with the present perfect or another tense. This is sometimes called 'details of news'.

- I've hurt my leg. I fell off a ladder when I was painting my bedroom.
- I've been on holiday. I went to Spain and Portugal.

4: For stories or lists of events, we often use the past simple for the actions in the story and the past continuous for the background.

- He went to a café. People were chatting and music was playing. He sat down and ordered a coffee.

Unreal or imaginary things in the present or future.

5: We use the past simple to talk about things that are not real in the present or future. So we use it with the second conditional and after words like 'wish'.

- If I won the lottery, I would buy a house.
- I wish I had more time!

When should we use the Past Continuous called the Past Progressive?

1: An action in the past which overlaps another action or a time. The action in the past continuous starts before and often continues after the other shorter action or time.

- I was walking to the station when I met John. (I started walking before I met John, and maybe I continued afterwards.)
- At three o'clock, I was working. (I started before three o'clock and finished after three o'clock.)

2: In the same way, we can use the present continuous for the background of a story.
(We often use the past simple for the actions.) This is really a specific example of Use 1.

- The birds were singing, the sun was shining and in the cafés people were laughing and chatting. Amy sat down and took out her phone.

3: Temporary habits or habits that happen more often than we expect in the past. We often use 'always, constantly' or 'forever' here. This is the same as the way we use the present continuous for habits, but the habit started and finished in the past. This thing doesn't happen now.

- He was always leaving the tap running .
- She was constantly singing.

4: To emphasize that something lasted for a while. This use is often optional and we usually use it with time expressions like 'all day' or 'all evening' or 'for hours'.

- I was working in the garden all day.
- He was reading all evening.

Remember you can't use this tense or any continuous tense with stative verbs.

When should I use the Past Perfect Simple?

1: A finished action before a second point in the past.

- When we arrived, the film had started (= first the film started, then we arrived).

We usually use the past perfect to make it clear which action happened first. Maybe we are already talking about something in the past and we want to mention something else that is further back in time. This is often used to explain or give a reason for something in the past.

- I'd eaten dinner so I wasn't hungry.
- It had snowed in the night, so the bus didn't arrive.

If it's clear which action happened first (if we use the words 'before' or 'after', for example), the past perfect is optional.

- The film started before we arrived / the film had started before we arrived.

2: Something that started in the past and continued up to another action or time in the past.

The past perfect tells us 'how long', just like the present perfect, but this time the action continues up to a point in the past rather than the present. Usually we use 'for + time'. We can also use the past perfect continuous here, so we most often use the past perfect simple with stative verbs.

- When he graduated, he had been in London for six years. (= He arrived in London six years before he graduated and lived there until he graduated, or even longer.)
- On the 20th of July, I'd worked here for three months.

3: To talk about unreal or imaginary things in the past. In the same way that we use the past simple to talk about unreal or imaginary things in the present, we use the past perfect (one step back in time) to talk about unreal things in the past. This is common in the third conditional and after 'wish'.

- If I had known you were ill, I would have visited you.
- She would have passed the exam if she had studied harder.
- I wish I hadn't gone to bed so late!

When should I use the Past Perfect Continuous?

1: Something that started in the past and continued up to another action or time in the past.

The past perfect continuous tells us 'how long', just like the present perfect continuous, but this time the action continues up to a point in the past rather than the present. Usually we use 'for + time'. (We can also use the past perfect simple here, often with stative verbs)

- She had been working at that company for a year when she met James.

- I'd been walking for hours when I finally found the house.
- We'd been living in Berlin for three months when we had to leave.

2: Something that finished just before another event in the past. This is usually used to show a result at a time in the past. It's very similar to the present perfect continuous, but the action finishes before another time in the past, rather than finishing before the present.

- The pavement was wet, it had been raining. (The rain had finished before the time I'm describing in the past. We could see the result of the rain.)
- The children had been playing and so the room was a mess!
- I'd been working before I saw you and that's why I was really tired.

When should I use the Future Simple?

Will

1: We use the future simple with 'will' to predict the future. It is the basic way we talk about the future in English, and we often use it if there is no reason to use another future tense. We can use it for future facts and for things that are less certain.

- The sun will rise at 7am. • I think the Conservatives will win the next election.

2: Promises / requests / refusals / offers. This is sometimes called 'volitional' will. It's about wanting to do something or not wanting to do something in the future. • I'll help you with your homework. • Will you give me a hand?

- I won't go!

In a similar way, we often use 'will' when we're talking about a decision at the moment of speaking. We are usually making an offer or promise or talking about something that we want to do.

- A: I'm cold. B: I'll close the window.

3: We use the simple future with 'will' in the first conditional, and in other sentences that have a conditional feeling.

- If it doesn't rain, we'll go to the park. • Let's arrive early. That will give us time to relax.

Shall

'Shall' is used mainly in the forms 'shall I?' and 'shall we?' in British English. These forms are used when you want to get someone's opinion, especially for offers and suggestions.

- Shall I open the window? (= Do you want me to open the window?)
- Where shall we go tonight? (= What's your opinion?)

Be going to

1: We often use 'be going to' to talk about our future intentions and plans. We have usually made our plans before the moment of speaking.

- A: We've run out of milk. B: I know, I'm going to buy some.

2: We can also use 'be going to' to make a prediction about the future. Often it's possible to use both 'be going to' and 'will' but it's more common to use 'be going to' if we can see evidence in the present.

- Look at those boys playing football! They're going to break the window.
- The sky is getting darker and darker. It's going to rain.

When should I use the Future Continuous?

1: We use the future continuous to talk about an action in the future that overlaps another, shorter action or a time. The action in the future continuous usually starts before and might continue after the second action or time. This is very similar to how we use the past continuous in the past. The verb after 'when' is usually in the present simple.

- I'll be waiting when you arrive. • At eight o'clock, I'll be eating dinner.

2: We can use the future continuous to talk about something that will happen if everything happens as we expect. This is sometimes called 'future as a matter of course'. It's usually possible to choose the future simple as well, but we often choose the future continuous because then it's clear that we are not making a request or offer.

- The Government will be making a statement later.
- When will you be leaving? (This is more polite than 'when will you leave?' because it's definitely not a request for you to leave)

Remember, we can't use the future continuous with stative verbs, so if we want to use a stative verb in one of the situations where we need to the future continuous, then we use the future simple with 'will'.

When should I use the Future Perfect Simple?

1: We use the future perfect to say 'how long' for an action that starts before and continues up to another action or time in the future. Usually we need 'for'. We can also use the future perfect continuous here so we often use the future perfect simple with stative verbs. If we use 'when', we usually need the present simple.

- When we get married, I'll have known Robert for four years.
- At 4 o'clock, I'll have been in this office for 24 hours.

Sometimes we could also use the present perfect in the same situation. But we like to use the future perfect to make the time an easy number.

- I've lived here for 11 months and three weeks. (This is correct, but the time is not an easy number.)
- On Tuesday, I will have lived here for one year. (A much easier number)

2: We use the future perfect with a future time word, (and often with 'by') to talk about an action that will finish before a certain time in the future, but we don't know exactly when.

- By 10 o'clock, I will have finished my homework. (= I will finish my homework some time before 10, but we don't know exactly when.)
- By the time I'm sixty, I will have retired. (= I will retire sometime before I'm sixty. Maybe when I'm fifty-nine, maybe when I'm fifty-two.)

When should I use the Future Perfect Continuous?

1: Just like with the other perfect continuous tenses, we can use the future perfect continuous to say 'how long' for an action that continues up to another point in the future. The second point can be a time or another action. Generally, we need 'for + length of time' and if we use 'when' or 'by the time', we usually use the present simple.

- In April, she will have been teaching for twelve years.
- By the time you arrive, I'll have been cooking for hours!

In the same way as with the future perfect simple, we often use the future perfect continuous because we like easy numbers. It's also possible to use the present perfect continuous, but then we get a more complicated number.

- I've been working here for 11 months and three weeks. (This is correct, but the time is not an easy number.)
- On Tuesday, I will have been working here for one year. (A much easier number)

2: We can use the future perfect continuous, like the other perfect continuous tenses, to talk about something that finishes just before another time or action (in this case, in the future).

It's often used because there will be a result at the second point in the future. (Again, if we use 'when' we usually need the present simple)

- When I see you, I'll have been studying, so I'll be tired.

Stative Verbs

Stative verbs often relate to:

- Thoughts and opinions: agree, believe, doubt, guess, imagine, know, mean, recognise, remember, suspect, think, understand
- Feelings and emotions: dislike, hate, like, love, prefer, want, wish
- Senses and perceptions: appear, be, feel, hear, look, see, seem, smell, taste
- Possession and measurement: belong, have, measure, own, possess, weigh.

Reference: www.perfectenglishgrammar.com
https://www.perfect-english-grammar.com/verb-tenses.html

PART FIVE

COMMON IRREGULAR VERBS

Infinitive	**Past Simple**	**Past Participle**
be	was/were	been
become	became	become
begin	began	begun
bring	brought	brought
buy	bought	bought
choose	chose	chosen
come	came	come
do	did	done
drink	drank	drunk
drive	drove	driven
eat	ate	eaten
fall	fell	fallen
feel	felt	felt
find	found	found
fly	flew	flown
forget	forgot	forgotten
get	got	got (gotten In USA)
give	gave	given
go	went	gone
have	had	had
hear	heard	heard
keep	kept	kept
know	knew	known
leave	left	left
lend	lent	lent
let	let	let
lose	lost	lost
make	made	made
meet	met	met
pay	paid	paid
put	put	put
read	read	read (pronounced /red/)
run	ran	run
say	said	said
see	saw	seen
sell	sold	sold
send	sent	sent
sing	sang	sung
sit	sat	sat
sleep	slept	slept
speak	spoke	spoken
stand	stood	stood
swim	swam	swum
take	took	taken

teach	taught	taught
tell	told	told
think	thought	thought
understand	understood	understood
wear	wore	worn
write	wrote	written