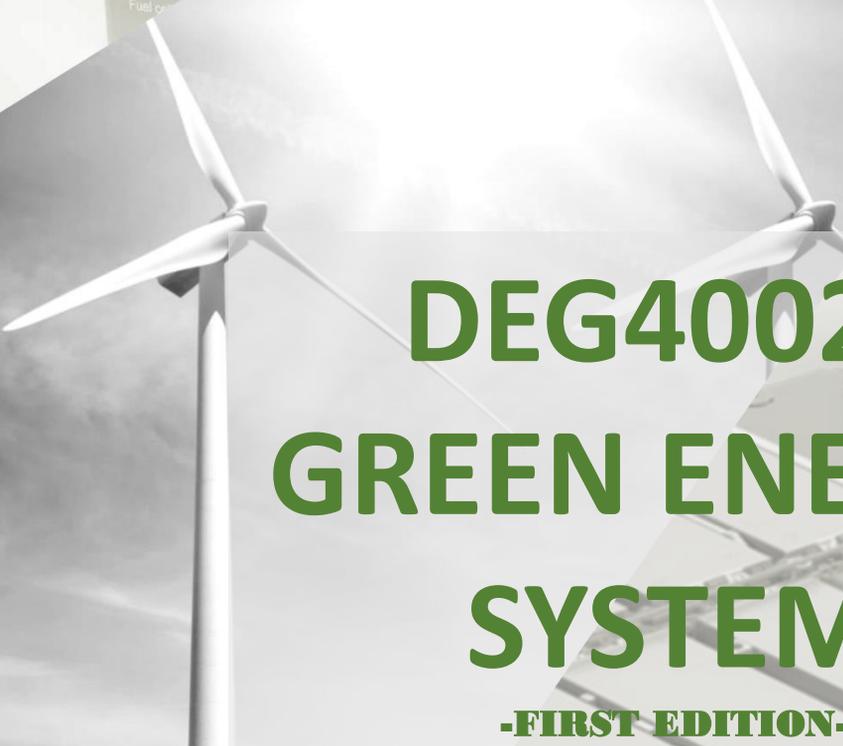




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POLITEKNIK
MALAYSIA
PORT DICKSON



DEG40023 GREEN ENERGY SYSTEM

-FIRST EDITION-

DEPARTMENT OF ELECTRICAL ENGINEERING



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We hereby declare that this module is our original work. To the best of our knowledge it contains no materials previously written or published by another person. If there is any, the authors have been acknowledgement and credit are mentioned accordingly.

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SOLAR PHOTOVOLTAIC POWER SYSTEMS



CHAPTER

01

- ✓ Types of solar photovoltaic system
- ✓ Charge controller and batteries
- ✓ Inverters

Following are 4 types of Solar Photovoltaic Systems:

- Grid-connected PV system (GCPV)
- Grid-connected PV System with Battery Backup
- Off-Grid PV System (OGPV)
- Hybrid PV System

GCPV



A grid-connected PV (GCPV) system consists of PV modules, an inverter, a BOS, and other components that are all connected to the utility grid.

GCPV WITH BATTERY



A PV system that is "Grid-Connected with Battery Backup" is made up of one or more specific AC circuits that are not directly connected to the electric grid.

OGPV



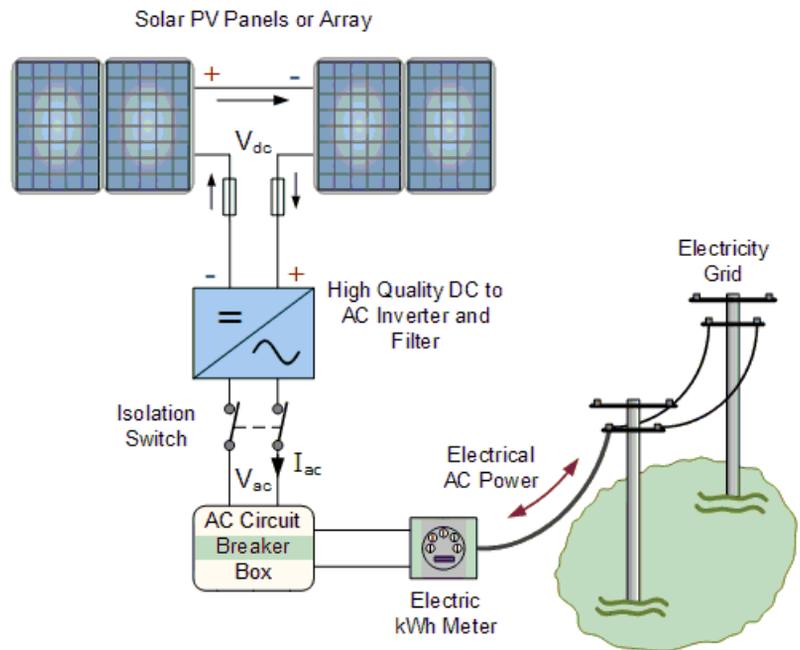
A basic off-grid OR stand-alone system consists of a renewable energy source that produces direct current (DC), a battery bank that stores the DC power, a charge unit, and an inverter.

HYBRID



Hybrid photovoltaic systems most commonly take the form of photovoltaic systems combined with wind turbines or diesel generators.

GCPV SYSTEM



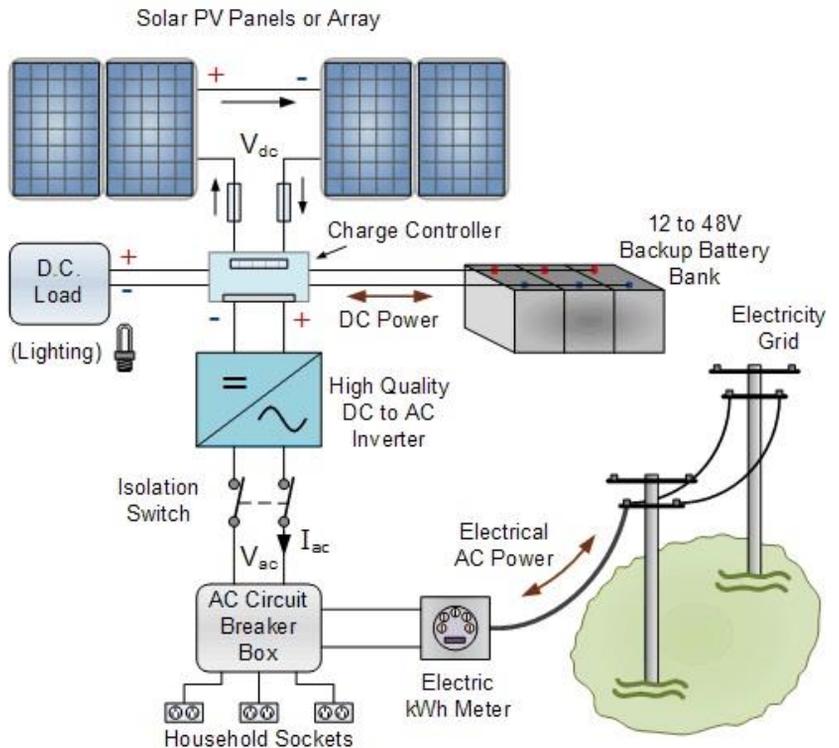
Basic Schematic Diagram

Inverter – The function of inverter extracts as much DC (direct current) from the PV array as possible and converts it to AC (alternating current) before transfer to national grid.

AC Breaker Panel and Fuses – With the exception of additional breakers for inverter and/or filter connections, a breaker panel or fuse box is the most common type of fuse box included with a household power supply and installation.

Electricity Meter – The electric meter, also known as a kWh meter, is used to record the flow of electricity to and from the grid. Twin kWh meters can be used, one to indicate the amount of electrical energy consumed and the other to record the amount of solar electricity sent to the grid.

GCPV WITH BATTERY SYSTEM



Photovoltaic System With Battery Backup Diagram

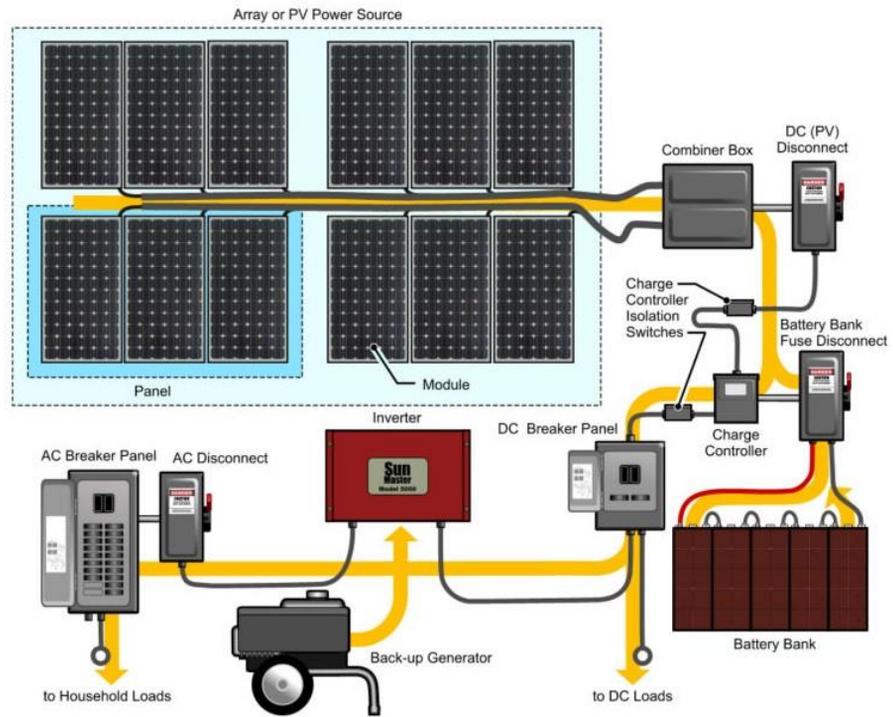
Charge controller protects from overcharging and overvoltage by preventing overcharging.

Battery bank is a collection of batteries wired in series or parallel. Compared to using a single battery, that allows for even more power to be stored.

Safety Switches and Cabling is a Isolation switches rated for the array's maximum DC voltage and current. Its must be provided, as well as inverter safety switches with better accessibility to disconnect the system.

The Electricity Grid – It is connected to the National grid.

OGPV WITH BATTERY SYSTEM

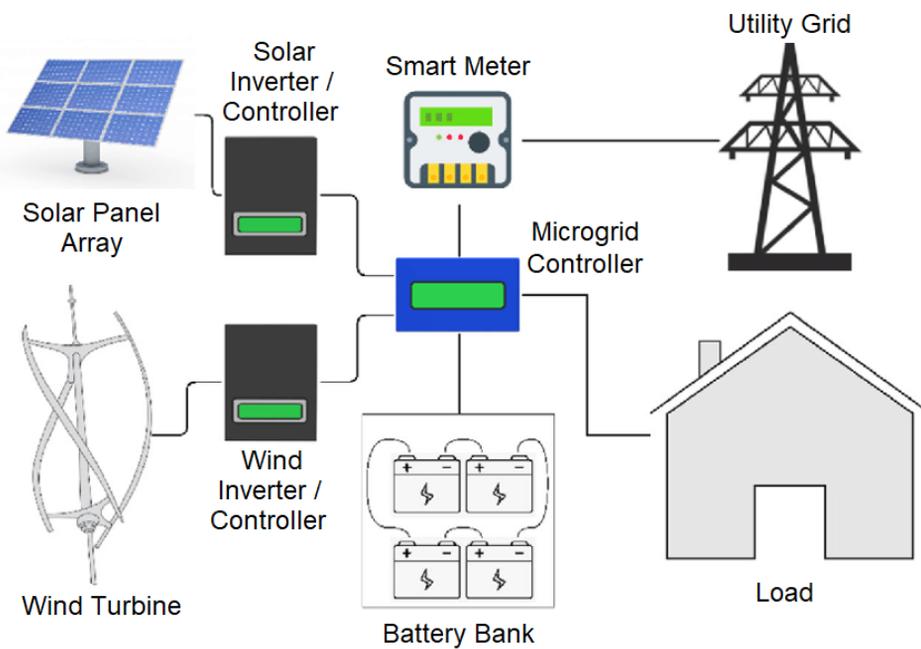


OGPV with Battery System Diagram

A simple off-grid or stand-alone system consists of a renewable energy source that generates DC power, a battery bank that stores the DC power, as well as an inverter and charger controller..

A **backup generator** or an emergency generator provides additional reliability and continuity to your power supply

HYBRID SYSTEM



Hybrid System Diagram

The aerodynamic force of the rotor blades is used to convert wind energy into electricity in a wind turbine.

A **wind charge controller** is an electronic device that ensures that your turbine not to over charge your batteries and limit the speed of the wind turbine blades enabling them to spin when the batteries are in full capacity or in high wind situations..

Solar Charge Controller

A charge controller, charge regulator, or battery regulator, is a device used to controls the electric current through batteries.

PWM (Pulse Width Modulation)

PWM solar charge controller is a wonderful low-cost choice. If more than one panel is utilized, make sure they are linked in parallel rather than series.

MPPT (Maximum Power Point Trackers)

MPPT controllers are more advanced than PWM controllers in that they allow the solar panel to function at its maximum power point.

TYPE OF SOLAR BATTERIES

Floded lead acid batteries

- Used at stand-alone alternative energy systems due to their lengthy lifespan.
- Need the battery maintenance for regular basic such as watering, equalizing charges and keep the top terminals clean..

Sealed lead acid batteries

- Widely used in solar electric systems.
- Suitable for solar systems that are connected to the grid and have a battery backup.

Lithium (LiFePO₄) batteries

Due to their high efficiencies and extended cycle life, LiFePO₄ batteries are an excellent alternative for stand-alone PV systems, providing they are operated with a charge control algorithm designed for lengthy charge durations, which are common in solar PV applications.

INVERTERS

GCPV Inverter

GCPV Inverter is classified based on capacity rating and topology.

OFF-GRID Inverter

Off-grid inverters are primarily intended for use with solar power systems for a home or office building that is **completely disconnected from the power grid**.

MULTIFUNCTION Inverter

Can function as both Stand-Alone and Synchronous inverters at the very same time.

Can you find a picture of Solar charger controller, batteries and inverters?

PV ARRAY MOUNTING

FREE-STANDING(FS) / POLE MOUNT

Pole Mount systems are suitable for installations with limited roof space, when shading is a concern, or when you want to get the most out of the solar array.

RETROFITTED (RT) – RACK MOUNT

Rack mounts can be customized to accommodate a range of situations, including ground and roof mounting.

RETROFITTED (RT) – STANDOFF MOUNT

Standoffs can be mounted on practically any type of tile roof, including batten, batten less, curve, and flat tile profiles.

BIPV – BUILDING INTEGRATED PHOTOVOLTAIC

BIPV used a Photovoltaic materials replaced traditional building materials in areas like the roof, skylights, and facades.



Tutorial

Question

1. Explain TWO (2) Principle operation of Charge Controller in Solar Photovoltaic Power System.
2. Write and explain the characteristics in the selection of the inverter used in Solar Photovoltaic Power System
3. State the differences of each type of Photovoltaic Array mounting in Solar Photovoltaic Power System.

WIND ENERGY POWER SYSTEM



CHAPTER

02

- ✓ Types of Wind Power System
- ✓ Components of Wind Power System
- ✓ Types of Generator Used In Wind Power System



Grid-tied system

Connecting to the utility grid without batteries

Grid-tied system with battery backup

Connecting to the utility grid with battery backup. It has access to the grid's whole capacity.

Off-grid system

Batteries are used in off-grid wind-electric systems. Suitable for the area are not connected to the grid.

Direct-drive Batteryless system

Commonly used to pump water. A Turbines connected to a pump.

Can you differentiate wind power system using a picture?

ADVANTAGES

Wind energy is a cost-effective option. After the production tax credit, land-based utility-scale wind is one of the cheapest energy sources accessible today, costing 1–2 cents per kilowatt-hour.

Jobs are created by the wind. Wind can sustain more than 600,000 jobs in manufacturing, installation, maintenance, and related services by 2050

It's an environmentally friendly fuel source. Wind energy does not contaminate the air in the same way as power plants that burn fossil fuels, such as coal or natural gas

DISADVANTAGES

On a cost basis, wind power still compete with conventional generation sources. Wind projects must be able to compete economically with the lowest-cost source of electricity.

Great wind sites are frequently found in rural places, far from the cities that require electricity. Transmission lines must be built to provide electricity from the wind farm to the town.

Wind energy may not be the most cost-effective use of land. Alternative services for land that might be more valuable than electricity generation from wind turbine.

Horizontal Axis Wind Turbine (HAWT)

HAWT (horizontal axis wind turbine) is also considered as one of the famous types of wind turbines. The main shaft of a HAWT is fixed in the **horizontal direction to the ground**, making it different from a **vertical axis wind turbine**.

Advantages:

High efficiency, the blades always move perpendicular to the wind, receiving power through the whole rotation, unlike vertical wind turbines

Disadvantages:

•High construction and installation costs. Large Machinery is needed.

Vertical Axis Wind Turbine (VAWT)

VAWT or **vertical axis wind turbine** is the most famous types of the wind turbine. The **main shaft** of the **VAWT** is fixed in the vertical direction to the ground.

Advantages:

•Does not have to be pointed towards the wind to be effective. VAWT creates a flexible location for the placement of the turbine in an area with varying wind directions.

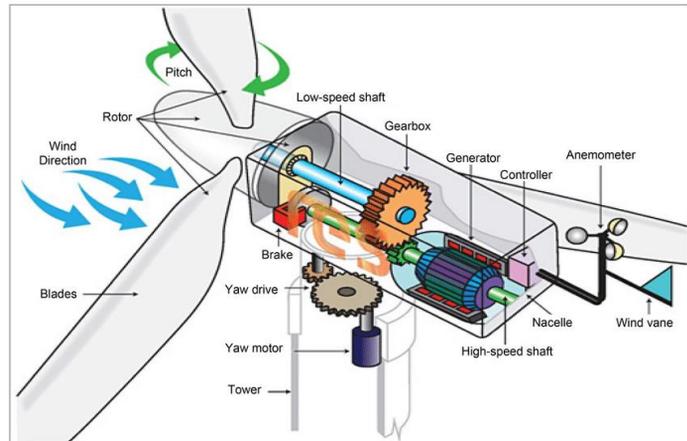
Disadvantages:

•The lower the place, the slower the wind. Slow wind reduces the efficiency of the turbines, which makes it less cost-effective.

Wind Turbine

Wind turbine component :

- a. Wind turbine
- b. Charge controller
- c. Dump load
- d. Battery bank
- e. System meter
- f. Main dc disconnect
- g. Inverter
- h. Ac breaker panel
- i. Backup generator
- j. Kilowatt-hour meter



Rotor System

The rotor has one or more blades and a hub. From a performance and total cost perspective, it is considered the essential component. The rotor may have one, two, three, or more blades.

Hub

A hub is the most important and major component of the horizontal axis wind turbine.

Power train subsystem

The power train system of the turbine has numerous electrical and mechanical parts that change the mechanical energy absorbed by the rotor hub into electrical energy.

Gearbox

Wind turbines rotate typically between 40 rpm and 400 rpm. Generators typically rotate at 1,200 to 1,800 rpm.

Blades

A wind turbine blade is used to obtain Kinetic Energy from the wind and transforms this energy into rotational power (mechanical power).

Tower

A tower is a component of the horizontal wind turbine that assists the rotor hub and the nacelle. This tower consists of steel lattice, concrete, or tubular steel.

Foundation

An excellent foundation is required to assist the tower and various components of the turbine, and the tower weight is in many **kilograms**.

Charger Controller

A charge controller, charge regulator or battery regulator **limits the rate at which electric current is added to or drawn from electric batteries**. It prevents overcharging and may protect against overvoltage.

Battery Bank / Storage

These stationary batteries use chemical interactions to safely store electricity from the renewable energy source so that it can be made available at a later time. **The wind turbine charges a bank of batteries, thus enabling efficient wind turbine power distribution throughout the grid.**

Wind System Meter

System meters **used to measure and display a several different aspects of wind power system status and performance**



Backup Generator

Provide electricity during calm periods when the wind doesn't blow.

Main DC Disconnect

*Disconnect between the batteries and inverter is required. This breaker **allows the inverter to be quickly disconnected from the batteries** for service, and protects the inverter-to-battery wiring against electrical fire.*

Kilowatt-Hour Meter

Keep track of how much electricity is used and how much is produced by the system. KWH metres are available in single phase and three phase versions.

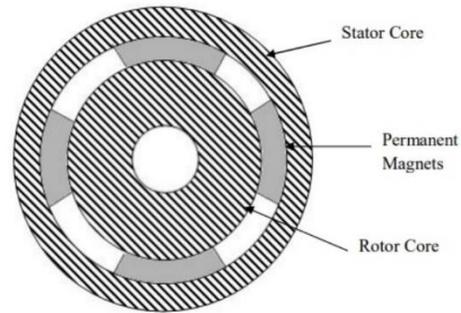
Inverter

*Inverters **take direct current (DC) power and change it into alternating current (AC) power.** For most small-scale power generation, the power coming out from the wind turbine is DC power.*

AC Breaker Panel

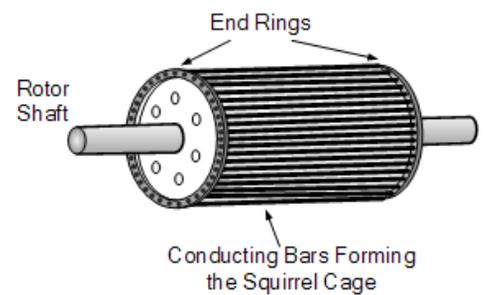
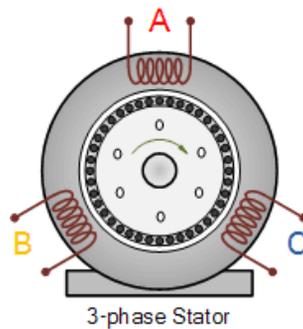
The AC breaker panel or main panel is a point where all residential electrical wiring meets with the electricity provider (grid or a wind-electric system).

PSMG

Permanent Magnet Synchronous Generator

- For the conversion of mechanical energy into electrical energy, the Permanent Magnet Synchronous Generator (PMSG) relies on the field produced by the permanent magnet linked to the generator's rotor.
- In the same way as synchronous generators have two types of windings, the armature is wound on the stator and the field winding is wound on the rotor in the PMSG.

DFIG



The DFIG (double-fed induction generator) is a common generating principle in wind turbines. It is based on a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. Although the multiphase slip ring assembly can be avoided, there are issues with efficiency, cost, and size. A brushless wound-rotor doubly-fed electric machine is a better choice.

Furling

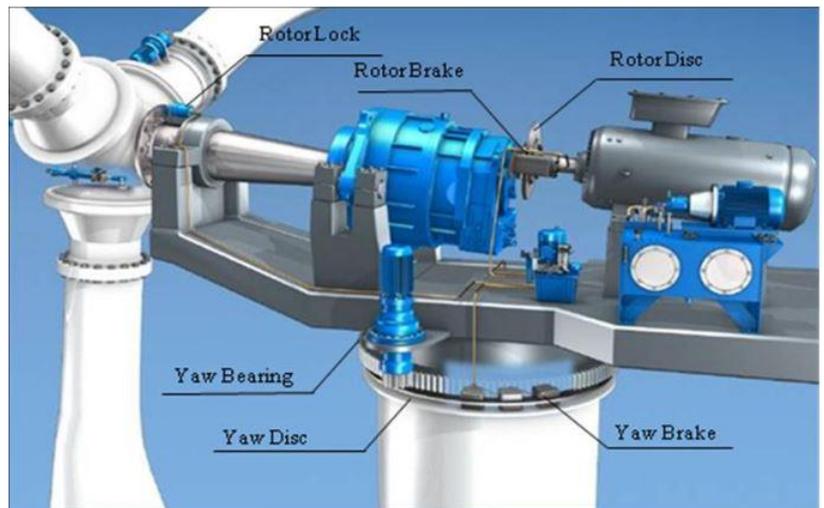
Furling is one method of preventing a wind turbine from spinning too quickly, simply by turning the blades away from the direction of the wind, either horizontally or vertically.

Blade Pitch

Nearly all large modern horizontal-axis wind turbines have **blade pitch control**. As the wind speed fluctuates, the control mechanism of a wind turbine adjusts the blade pitch to keep the rotor speed within working limits.

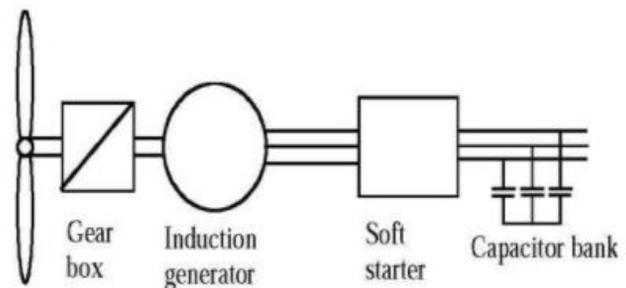
Shutdown Mechanism

Wind turbines are usually built to **shut down** when the wind speed reaches a level where the turbine might be damage.



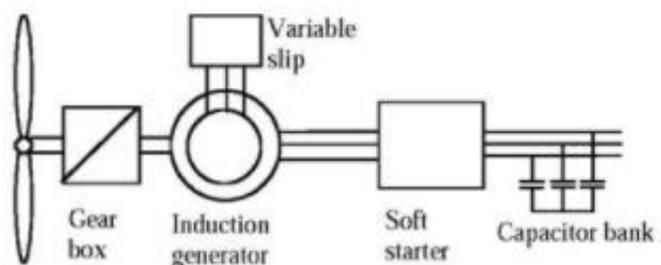
Fixed-speed Operation

Most wind turbines operated at **fixed speed** when producing power. In a start-up sequence the rotor may be parked (held stopped), and on release of the brakes, it would be accelerated by the wind until the required fixed speed was reached. At this point, a connection to the electricity grid would be made and then the grid (through the generator) would hold the speed constant. When the wind speed increased beyond the level at which rated power was generated, power would be regulated in either of the ways previously described, by stall or by pitching the blades.



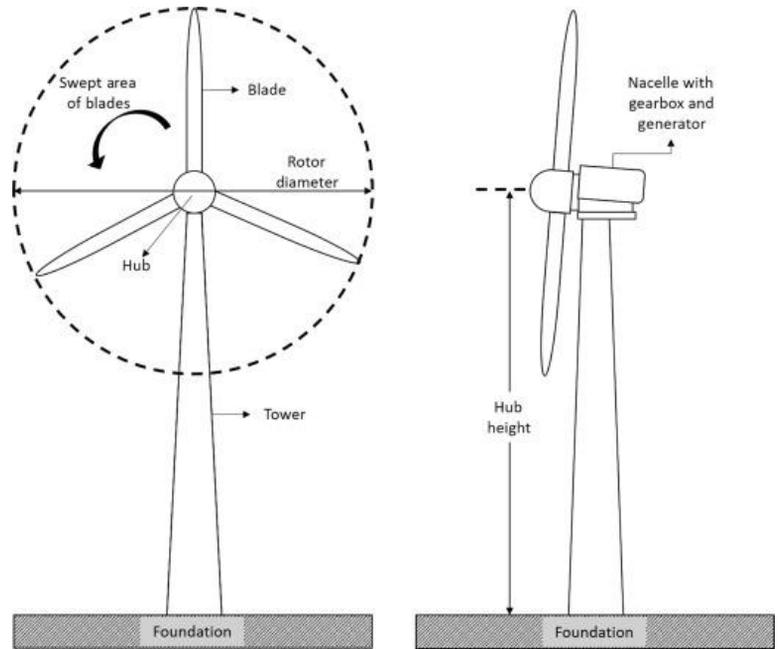
Variable-speed Operation

The introduction of **variable speed operation** allows the rotor and wind speed to be matched. The rotor maintained the best flow geometry for maximum efficiency. The rotor could be connected to the grid at low speeds in very light winds and would speed up in proportion to wind speed. As rated power was approached, and certainly after rated power was being produced, the rotor would revert to nearly constant speed operation, with the blades being pitched as necessary to regulate power.



Swept Area

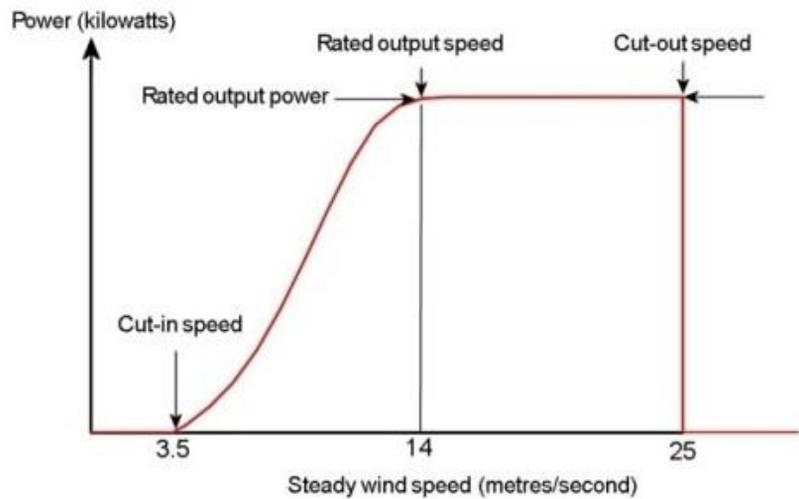
The area of the circle generated by the blades as they sweep through the air is referred to as the swept area.



The area swept by the blades has a direct relationship with the power production of a wind turbine. The more power it can take from the wind, the bigger the diameter of its blades.

Cut-in Speed

A turbine's cut-in and cut-out speed (also called 'cut-off speed') are determined by the manufacturer to protect the turbine from damage.



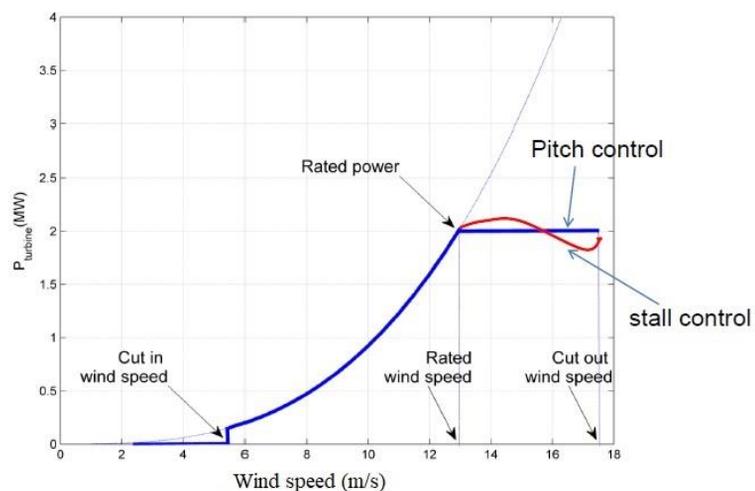
Typical wind turbine power output with steady wind speed.

Rated Power

As the wind speed increases, more electricity is generated until the rated speed is reached. The turbine's maximum, or rated, power is produced at this point.

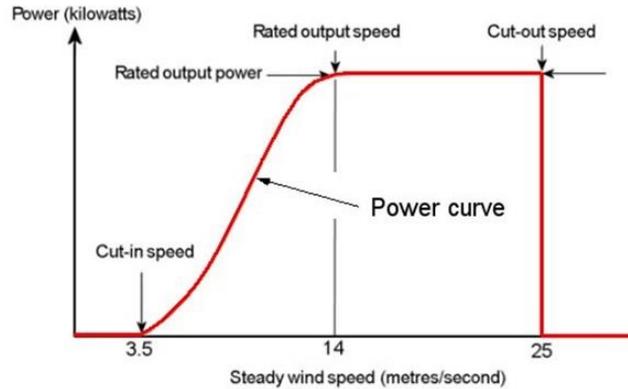
Power vs wind speed

Power output has to be limited according to generator capacity



Power Curve

Power Curve is a graph to show the typical relationship between power output from a wind turbine (power kilowatt) and wind speed (meters/second)



Free Standing Tower



**Truss tower
(Lattice)**



**Tubular tower
(Pole)**

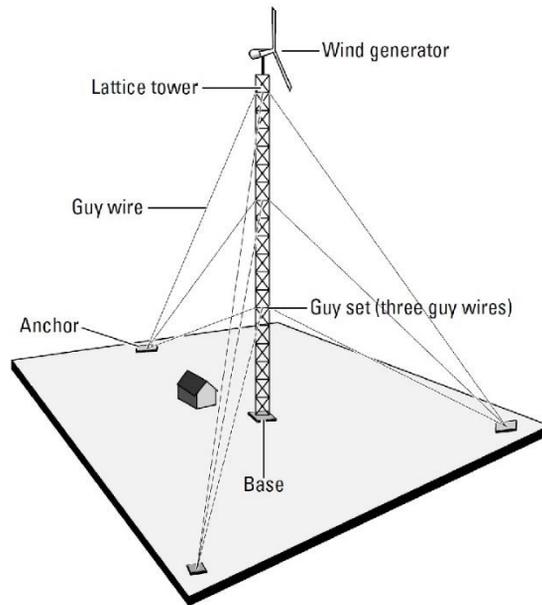
Lattice / Truss Tower

Self supporting lattice towers are an affordable alternative to guy wired towers..

Monopole / Tubular Tower

The Monopole Towers are widely used from our 1kW to 50kW wind turbines.

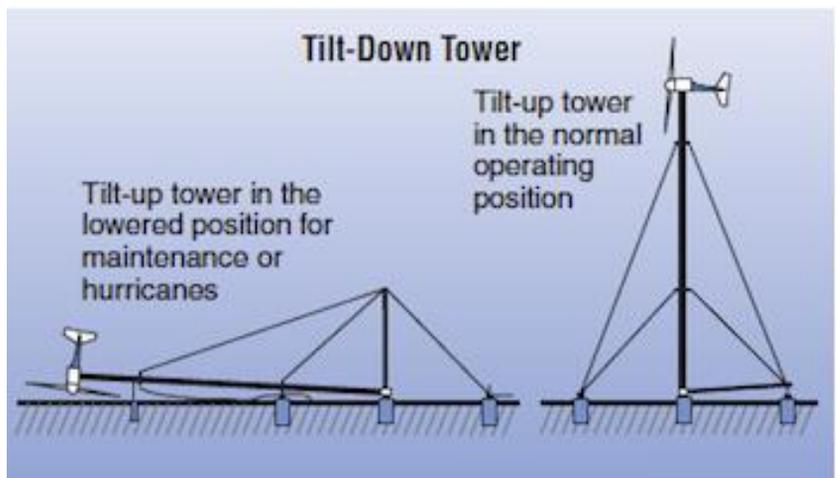
Fixed Guyed Tower



Guyed towers have a basic tower type, are straightforward to construct, and have a smaller single tower weight, which reduces steel consumption and construction costs.

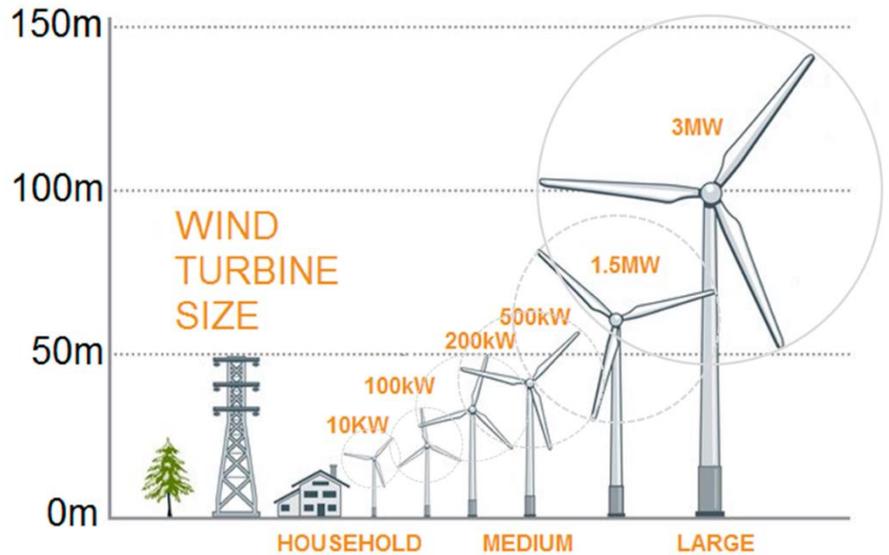
Tilt-up Tower

Guyed towers have a basic tower type, are straightforward to construct, and have a smaller single tower weight, which reduces steel consumption and construction costs.



Optimum Tower Height

The economic viability of a small wind power system is determined by the height of the tower. Taller towers allow turbines to receive better-quality winds more quickly, and even slight increases in wind speed result in exponentially more energy generated by the turbine. To put it another way, a taller tower implies significantly more energy — at a lower cost.



Solution For Lightning Protection

Because of their exposed location, height, and intricacy, lightning is much more to strike wind turbines. Lightning strikes cause of significant material and economic damage, it's critical to safeguard the turbines.

The major goal is to protect the rotor blades, bearings, and electrical systems against lightning damage. Onshore and offshore wind turbines both need to be available at all times.



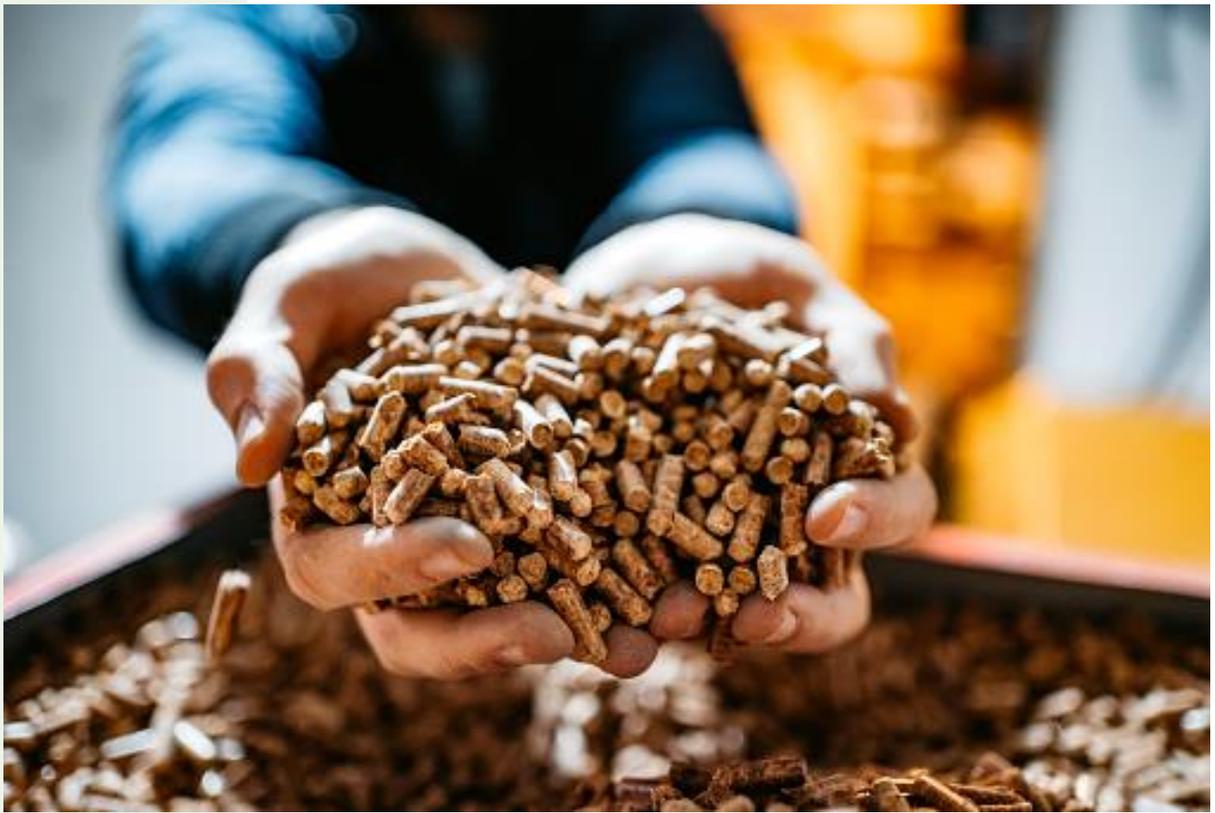


Tutorial

Structure Question

1. Draw a block diagram of an off-grid wind-electric systems system in wind power. (4 Marks)
2. Explain the block diagram anatomy of wind turbines for Horizontal Axis Wind Turbine (HAWT) in Wind Power System. (6 Marks)
3. Illustrate TWO(2) speed control mechanism used in the Wind Power System. (6 Marks)
4. Explain TWO (2) important factors to consider used in the wind power system. (6 Marks)

BIOENERGY POWER SYSTEM



CHAPTER

03

- ✓ Biomass Preparation
- ✓ Biomass Conversion Technologies.
- ✓ Power Generation Technologies

Bioenergy

Bioenergy is the term for electricity and gas produced from organic matter (biomass). Plants and wood, as well as agricultural and food waste even sewage can be used to create electricity or other form of power.



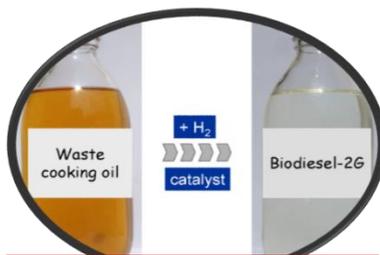
BIOMASS

Biomass is a fuel made from organic materials that is a renewable and sustainable source of energy that may be used to generate electricity or other types of power..

Biogas is a gas produced when microorganisms, particularly bacteria, decompose organic material in the absence of oxygen, which is equivalent to zero. Biogas is composed of 50-70 percent methane (CH₄), 25-45 percent carbon dioxide (CO₂), and a trace of other gases.



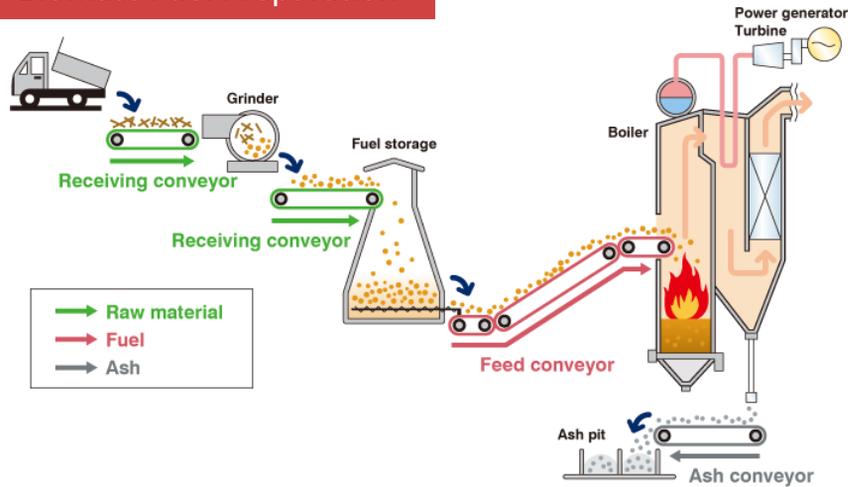
BIOGAS



BIOFUEL

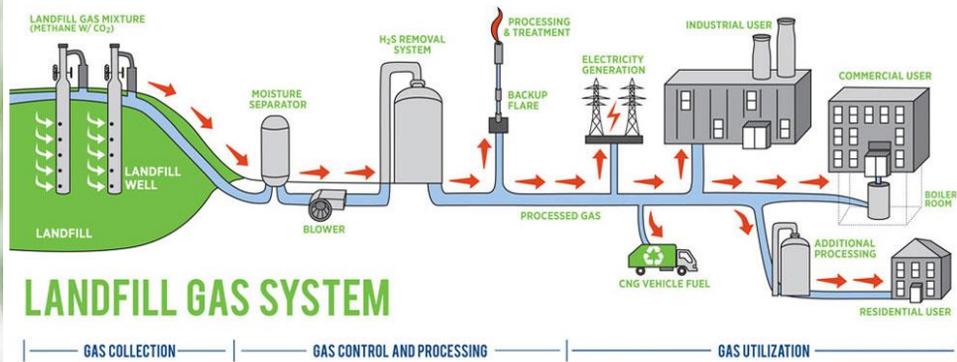
Biofuels are liquid fuels obtained from biomass, such as ethanol or biodiesel.

Biomass Fuel Preparation



Automatic biomass receiving and preparation system

Biogas Fuel Preparation



Biomass Conversion Technologies

Is a process of converting biomass into energy, which is then used to generate electricity.

Direct-fired and gasification systems are the two main types of biomass conversion technologies for electricity and heat production.

Direct Fire System

Direct burning of solid fuel biomass, with the resulting hot flue gases creating steam in a boiler, is the most typical use—a technology that goes back to the 19th century. Boilers currently use a range of fuels and play an important role in industrial process heating, commercial and institutional heating, and power generation. Boilers are distinguished by their configuration, size, and the quality of the steam or hot water they produce.

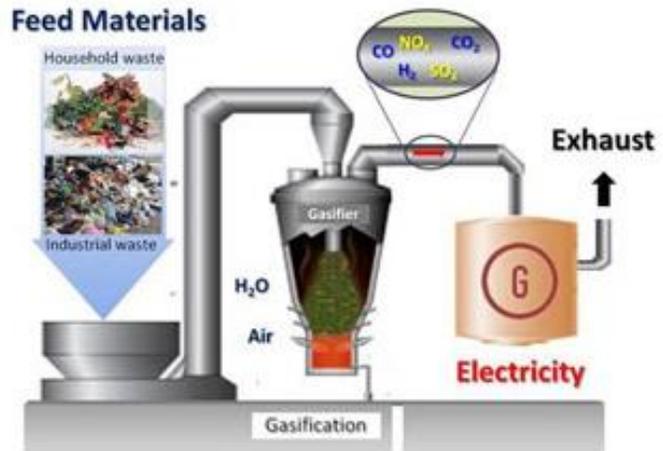


Direct Fire System

Gasification Technologies

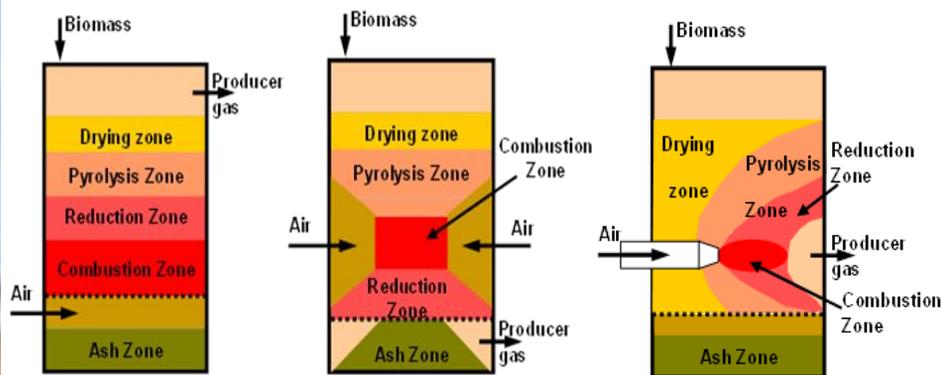
Gasification

Known as synthesis gas, its is a technological method for converting any carbonaceous (carbon-based) raw material, such as coal, into fuel gas (syngas).



Basic Gasification Diagram

Fixed Bed Gasifiers



UPDRAFT

(Biogas is collected above the bed as air flows up through the grate.)

DOWNDRAFT

(Biogas is produced as the air flows down through the bed and under the grate.)

CROSS DRAFT

(Biogas is produced when air flows over the bed).

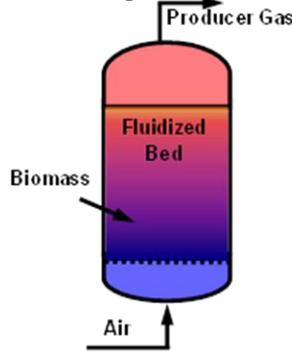
Fixed Gasification Diagram

Fluidized Bed Gasifiers

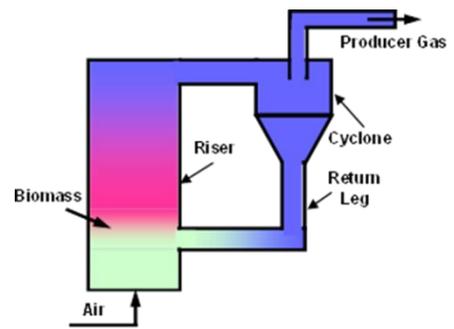
MAIN CLASSIFICATION FLUIDIZED BED GASIFIERS

Two type of Fluidized Bed Gasifier.

Bubbling Fluidized Bed and Circulating Fluidized Bed



Bubbling Fluidized Bed Gasifiers



Circulating Fluidized Bed Gasifiers

Gasifier

Advantages

Disadvantages

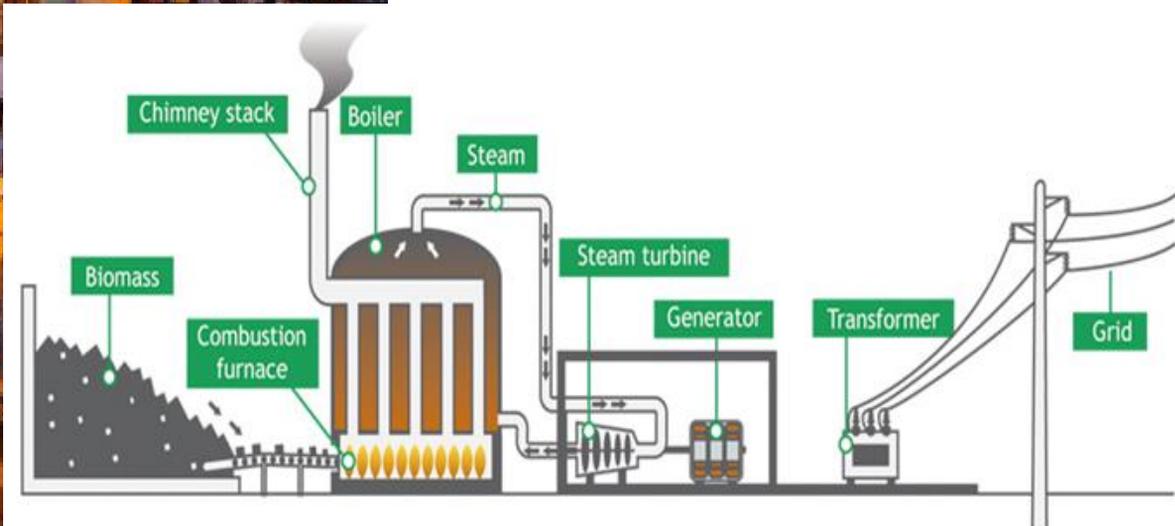
Updraft fixed bed	Mature for small-scale heal applications Can handle high moisture No carbon in ash	Feed size Limits High tar yields Scale limitations Low heating value gas Slagging potential
Downdraft fixed bed	Small-scale applications Low particulates Low tar	Feed size limits Scale limitations Low heating value gas Moisture-sensitive
Bubbling fluid bed	Large-scale applications Feed characteristics Direct/indirect heating Can produce higher heating value gas	Medium tar yield Higher particle loading
Circulating fluid bed	Large-scale applications Feed characteristics Can produce higher heating value gas	Medium tar yield Higher particle loading
Entrained flow fluid bed	Can be scaled Potential for low tar Potential for low methane Can produce higher heating value gas	Large amount of carrier gas Higher particle loading particle size limits

Type of Power Generation Technologies:

- Steam Turbine Technologies
- Gas Turbines Technologies
- Micro turbine Systems
- Reciprocating Internal Combustion
- Stirling System Generator

Steam Turbines Technologies

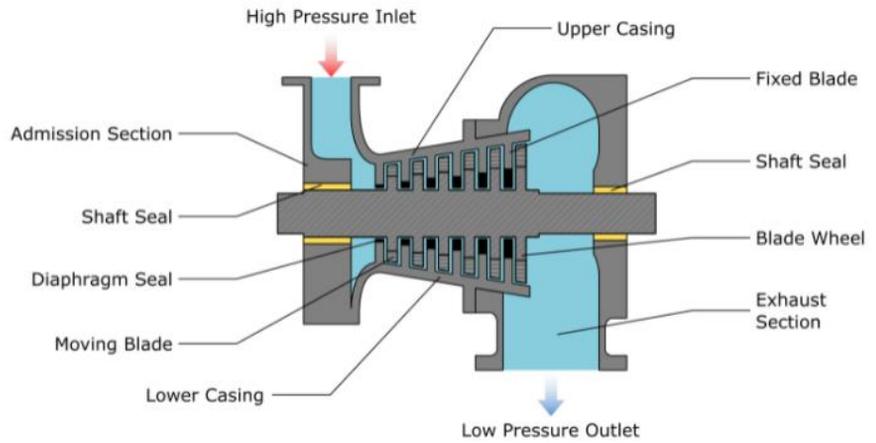
Incineration plants use steam turbines to recover steam generated by waste heat. Turbines are designed to deal with the varying heating rates that come with the waste burning process.



Steam Turbines Block Diagram



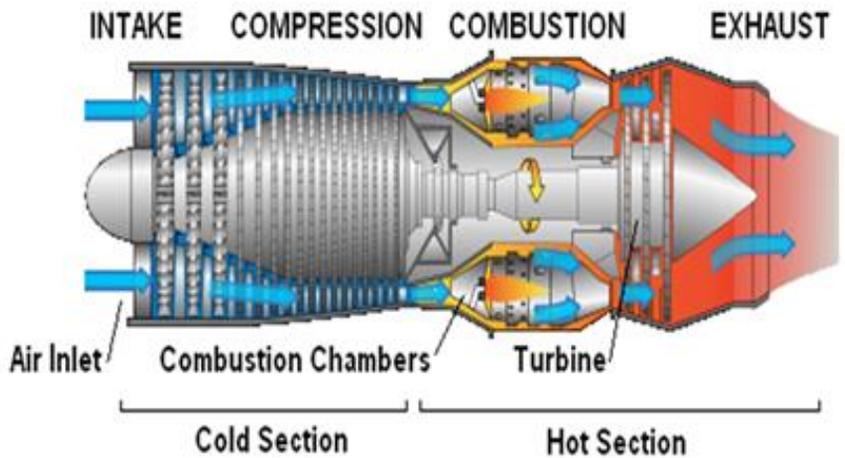
Steam Turbines Technologies



Turbine Construction and Components

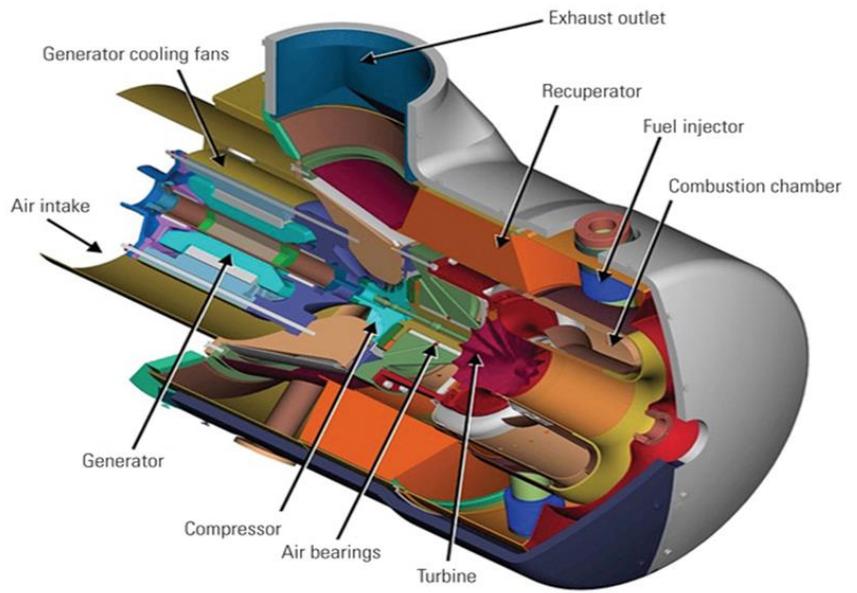
Components in Steam Turbines

Gas Turbines Technologies



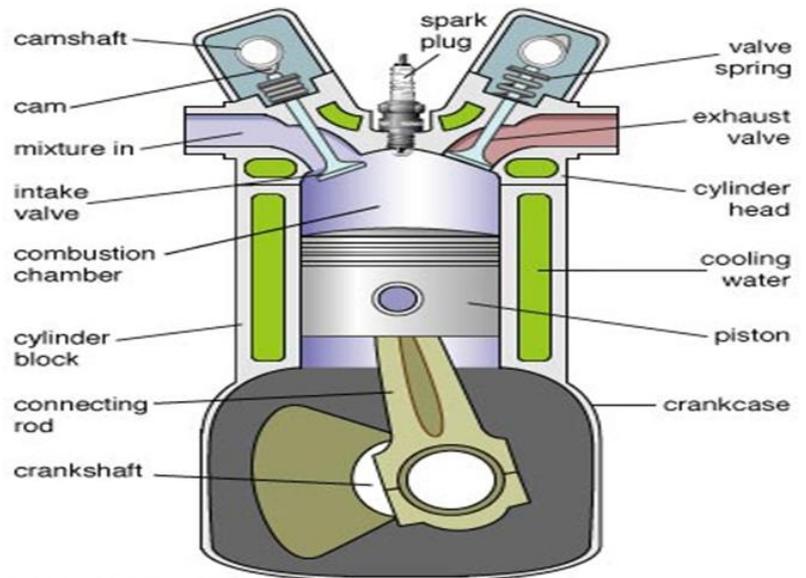
Components in Gas Turbines

Micro Turbines System



Components in Micro Turbines

Reciprocating Internal Combustion

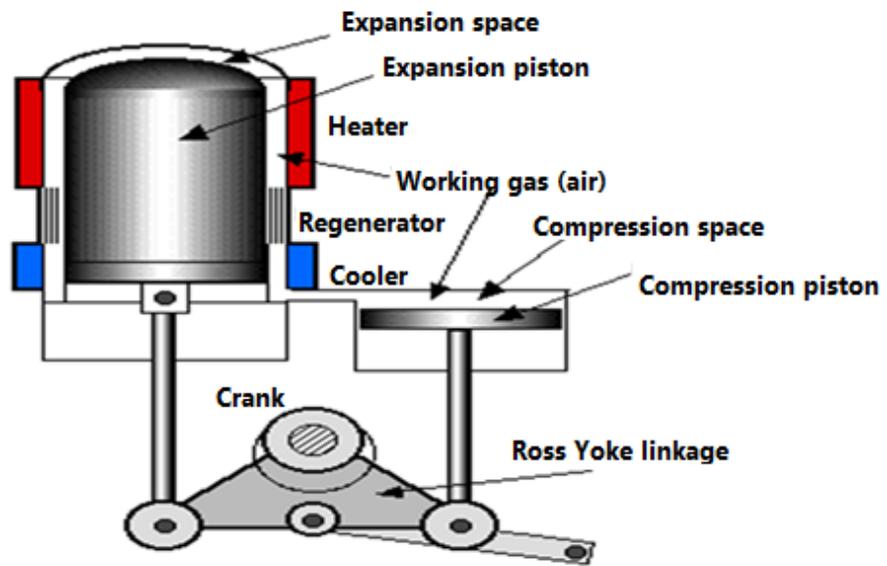


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Components in Reciprocating Internal Combustion



Stirling Engine



Components in Stirling Engine

Tutorial

CASE STUDY QUESTION 1:

- Identify the various technologies usage for **biomass power system**
- Discuss type of waste material in **biomass power system** for effective output voltage.
- Distinguish the advantages and disadvantages using **biomass and biogas power system** technologies.
- Describe the applicability biomass and biogas power system in Malaysia.

FUEL CELL POWER SYSTEM



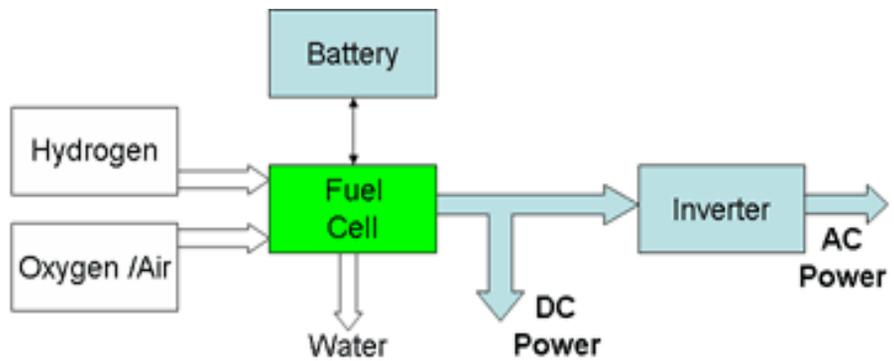
CHAPTER

04

- ✓ Fuel cell power systems
- ✓ Fuel processing systems
- ✓ Fuel cell power section systems

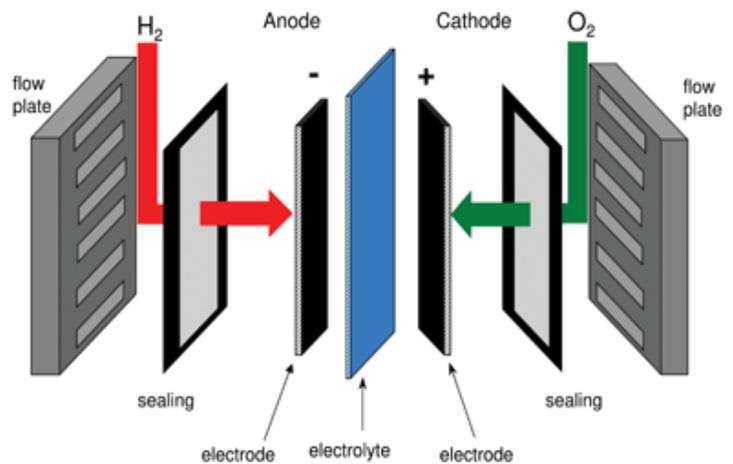
Fuel Cell

A fuel cell generates electricity cleanly and efficiently by using the chemical energy of hydrogen or other fuels. When hydrogen is utilized as a fuel, only energy, water, and heat are produced.

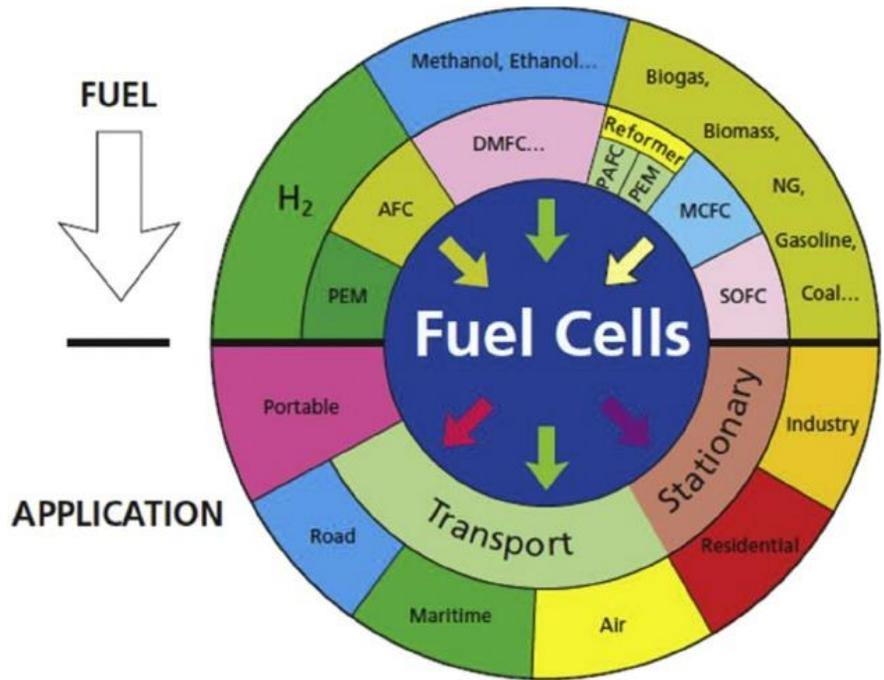


Fuel Cells

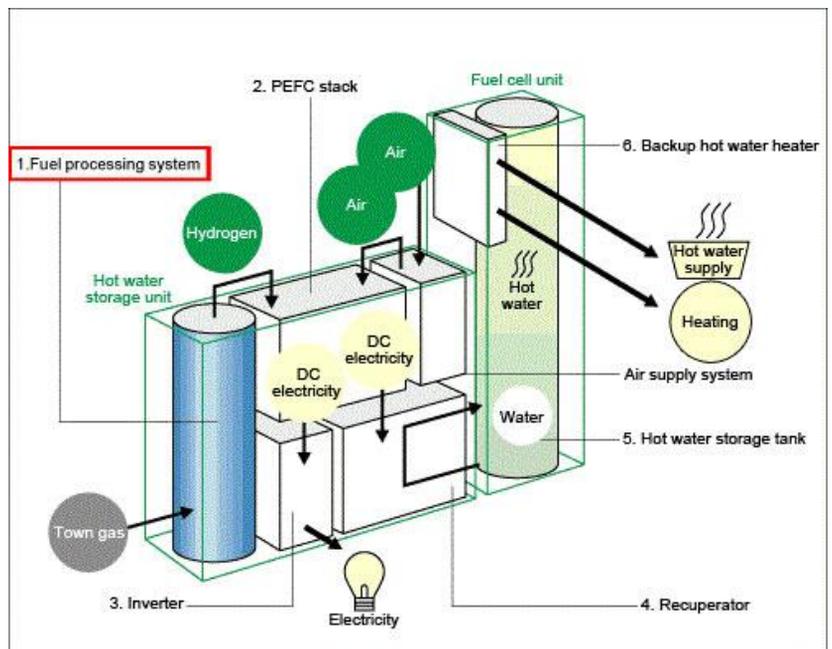
Fuel Cell Block Diagram



Fuel Cell Main Components



A fuel processing system produces hydrogen from city gas for use in fuel cells.



Proton Exchange Membrane Fuel Cells (PEMFCs)

Proton Exchange Membrane Fuel Cells (PEMFCs) are fuel cells that employ a polymer membrane as their electrolyte and the catalyst is a precious metal, often platinum.



Direct Methanol Fuel Cell (DMFC)



Direct Methanol Fuel Cells (DMFCs) employ a polymer membrane as an electrolyte and a platinum catalyst, similar to PEMFCs.

Alkaline Fuel Cell (AFC)

AFCs are most known for providing water and electricity to the crew of the NASA Apollo missions.



Phosphoric Acid Fuel Cell (PAFC)

A liquid phosphoric acid, ceramic electrolyte, and platinum catalyst are used in PAFCs. Physically, these fuel cells are comparable to PEM fuel cells, and they work at a similar efficiency level.



Molten Carbonate Fuel Cells (MCFCs)

Molten Carbonate Fuel Cells (MCFCs) use a molten carbonate-salt combination suspended in a ceramic matrix as an electrolyte and operate at temperatures up to 1200 degrees Fahrenheit.



Solid Oxide Fuel Cell (SOFC)

SOFCs, which operate at about 1800 degrees Fahrenheit, is the highest temperature fuel cells. SOFCs employ a thick layer of ceramic as an electrolyte, which enables oxygen ions to conduct at high temperatures.



Advantages of Fuel Cell

- High efficiency
- Clean. Carbon free when using H_2 and O_2 .
- Can use renewable fuels
- Do not need recharging.
- Can run continuously (as long as fuel is available)

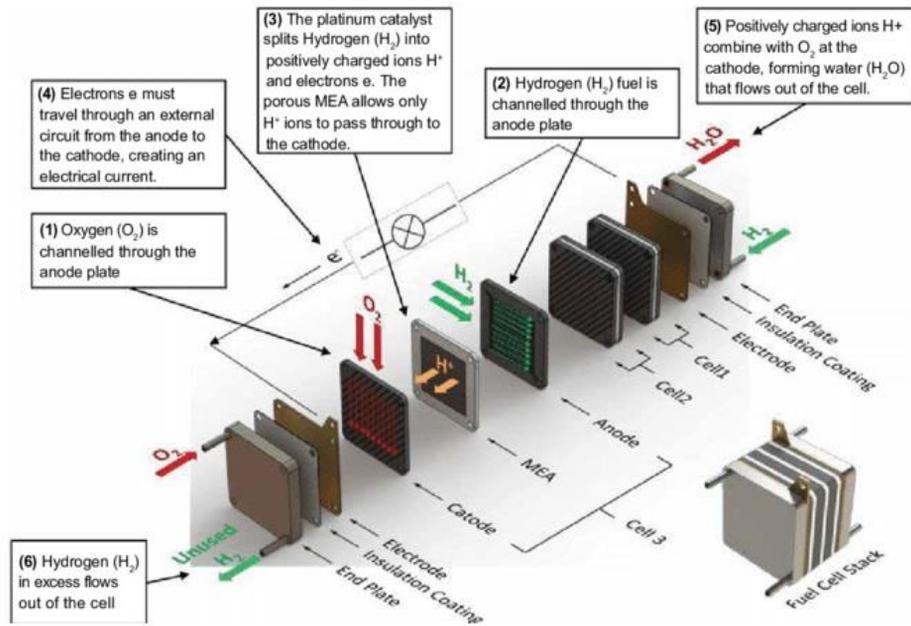
Disadvantages of Fuel Cell

- High cost due to expensive materials like platinum
- Requires fuel
- Reliability still evolving.
- Durability, particularly at high temperatures.



PEMFC

Proton exchange Membrane PEM fuel cells, also known as Polymer exchange membrane fuel cells, normally run on pure (99.999%) hydrogen fuel. The PEM fuel cell mixes hydrogen fuel with atmospheric oxygen to create water, heat (up to 90°C), and electricity.



Tutorial

ESSAY QUESTION

Using suitable diagram and sketching, explain how fuel cell can generate electricity. (20 Marks)



GREEN TRANSPORTATION SYSTEM



CHAPTER

05

- ✓ Types of alternative vehicles
- ✓ Architecture of alternative vehicles
- ✓ Energy storage solution in Electric Vehicles



Type of Alternative Vehicles

Types of green transportation

Train

Electric trains are less harmful to the environment, especially those that are powered by renewable energy.

Bicycles

Bicycling is an environmentally beneficial mode of transportation. It does not contribute to environmental pollution.

Scooter

Electric scooters offer no pollutants and do not require you to visit a petrol station to top up your tank because they are powered by a rechargeable battery.

Walking

Walking is the best and most convenient way to travel short distances.

Hybrid Car

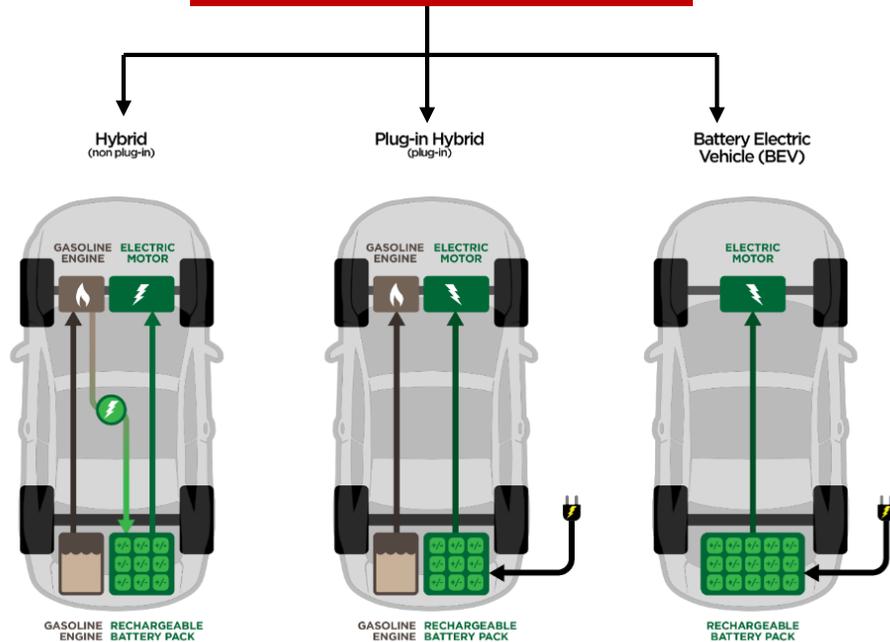
The great majority of hybrid cars are intended to recharge their batteries automatically by converting energy when braking.



Types of green transportation

The purpose of green transportation is to reduce the environmental damage due to individual's use of vehicles.

TYPES OF ALTERNATIVE VEHICLES



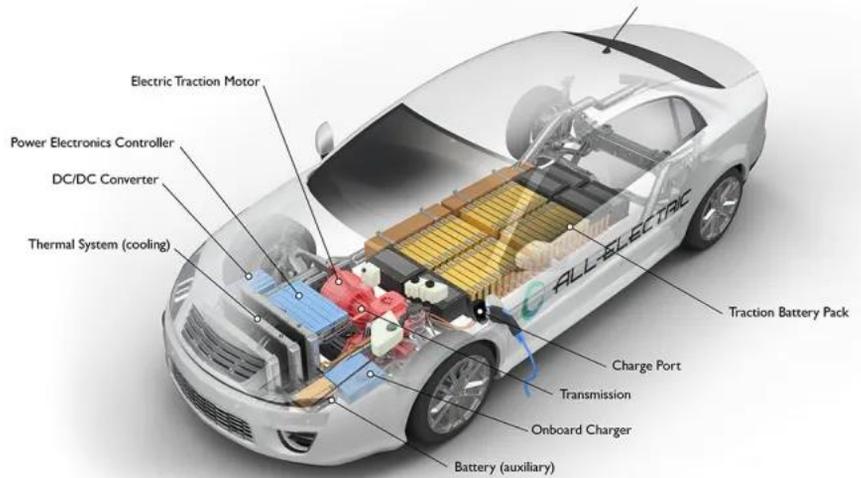
✓ An electric propulsion system is combined with a standard ICE propulsion system.

✓ A plug-in hybrid vehicle (PHEV) has an electric motor and an internal combustion engine (ICE) with a plug to connect to the electrical grid.

✓ EV operates with the help of an electric motor and a battery.

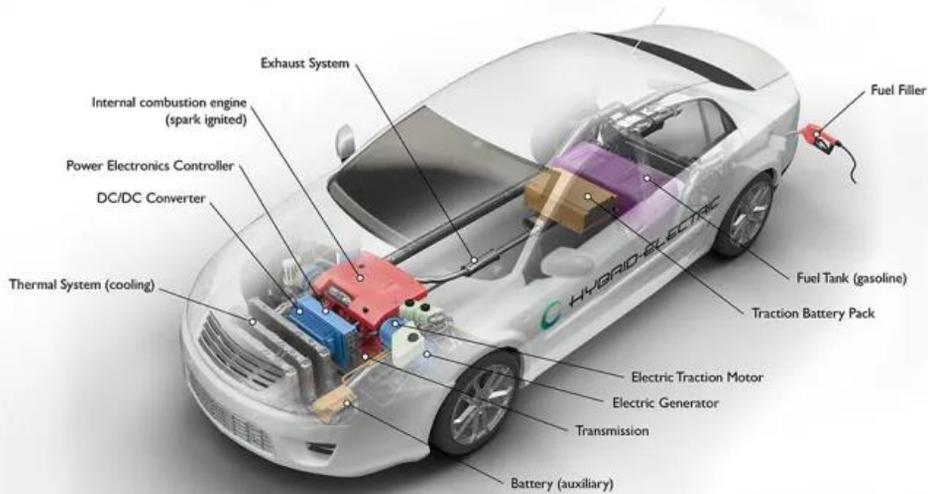


1. ELECTRIC VEHICLES



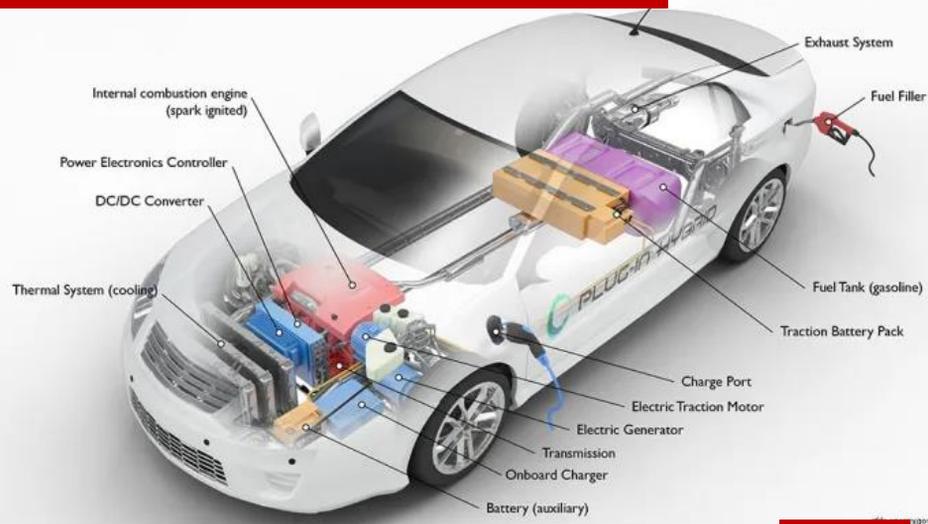
afdc.energy.gov

2. HYBRID ELECTRIC VEHICLES



afdc.

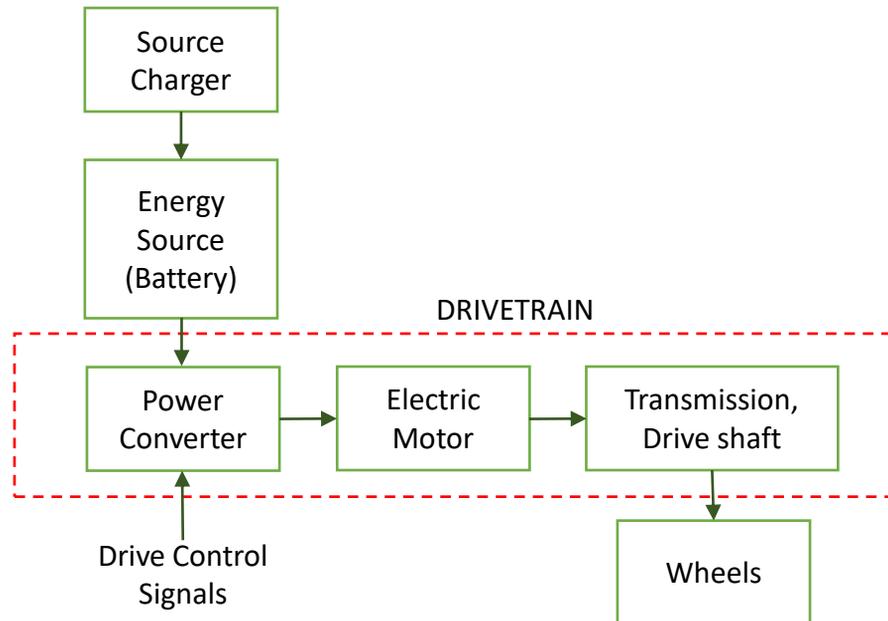
3. PLUG-IN HYBRID ELECTRIC VEHICLES



afdc.energy.gov

Architecture Of Alternative Vehicles

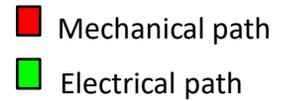
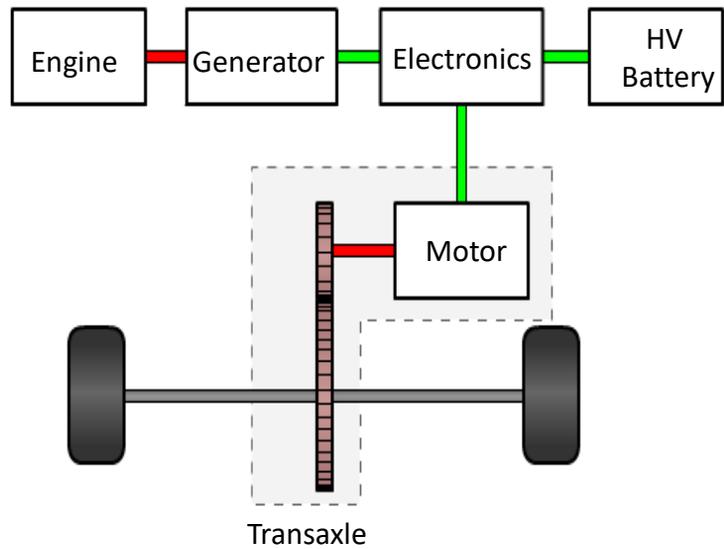
ARCHITECTURE OF ELECTRIC VEHICLES



COMPONENTS OF ELECTRIC VEHICLES

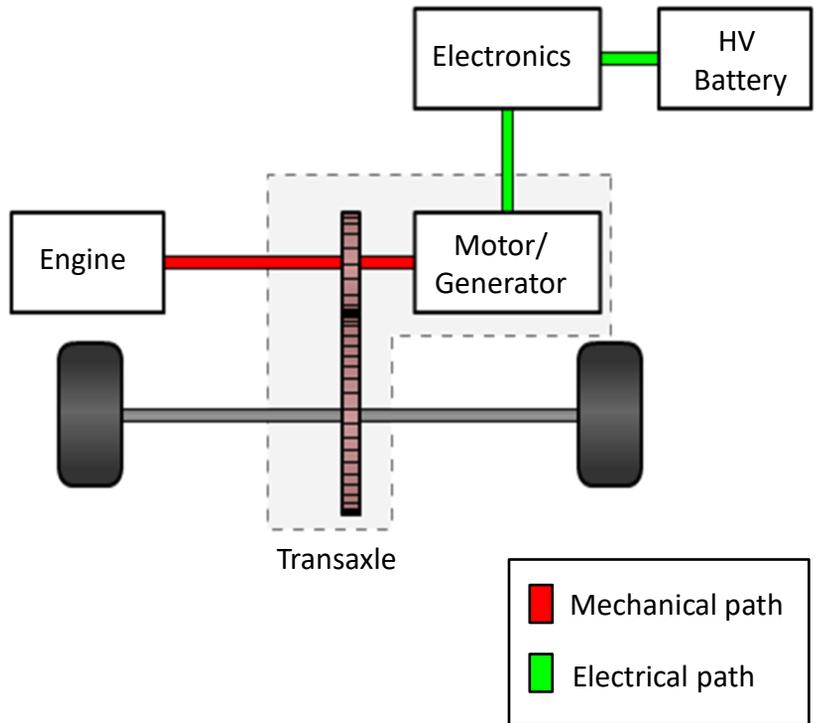
1. **Battery:** It powers the electric motor.
2. **Power Converter:** The electrical energy stored in the battery is fixed DC, and it must be transformed to variable DC or variable AC depending on the kind of electric motor used to move the wheels.
3. **Electric Motor:** In the beginning, DC series induction motors were employed. The focus has now switched to specialized electrical machinery.
4. **Clutch:** To change gears from low to high or vice versa, the engine must be detached from the wheels.
5. **Transmission:** The gearbox, also known as a transmission, permits power to be transferred from the engine to the wheels.
6. **Drivetrain:** The drivetrain is the combination of an electric motor, a clutch, and a gearbox.

1. Series Hybrid System



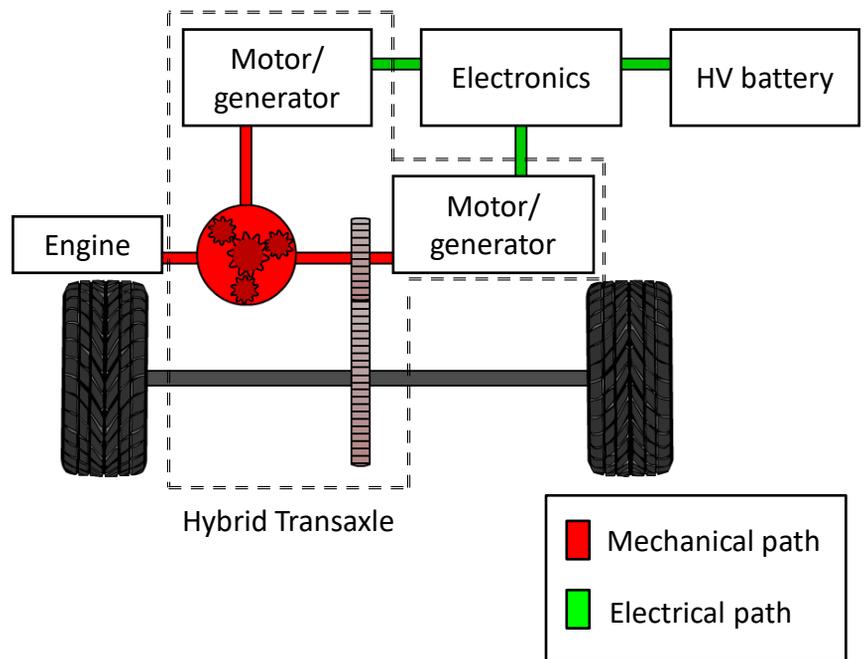
1. **IC Engine:** To generate electricity, series hybrids use a gasoline or diesel internal combustion engine (ICE) in conjunction with a generator.
2. **Electric Motor:** The vehicle is powered by an electric motor, which rotates a driveshaft that turn the wheels.
3. **Battery:** Regenerative braking reduces the operating time of the engine to charge the "HV Battery".

2. Parallel Hybrid System



1. **IC Engine:** Both an electric motor and an internal combustion engine are employed in a parallel hybrid system, which is more energy efficient.
2. **Electric Motor:** They can run in parallel, or one can be used as a main power source by kicking in to assist when additional power is needed
3. **Electronics (Power Converter):** It is tuned to work efficiently at higher speeds to reduce fuel consumption and emissions.

3. Series/Parallel Hybrid System



1. **IC Engine:** These vehicles can operate using electric motor alone or with assistance of the ICE.
2. **Electric Motor:** Consists of two motors that, depending on driving circumstances, employ either the electric motor or both the electric motor and the engine to reach the greatest degree of efficiency.

POWER REQUIREMENT FROM PROPULSION SYSTEM

Power requirement from propulsion system for;

1. Initial acceleration

The time and distance it takes a vehicle to accelerate from 0 to a specified high speed on a given terrain level defines its acceleration.

2. Rated vehicle velocity

The optimum mileage that can be achieved with constant battery energy if the EV is travelling at a certain speed is defined as the EV's velocity.

3. Maximum velocity

The maximum speed of a vehicle is defined as the steady cruising speed that it can reach with full power plant load on a level route.

4. Maximum grad ability

Grade ability refers to the gradient angle that a vehicle can withstand at a steady speed.





Energy Storage Solution in Electric Vehicles

THE CHARACTERISTIC OF BATTERY ENGINE AND GAS/PETROL ENGINE IN DIFFERENT DRIVING CONDITION.

Battery electric vehicles (BEVs) are propelled by an electric motor that draws power from batteries on board.

The BEVs lack the features of a conventional internal combustion engine (ICE), whose efficiency is much more dependent on load and engine speed than the electric motor.

BEVs may provide immediate torque as soon as the engine begins spinning.

Instead of turning that energy to heat via friction brakes, BEVs may utilize their electric motors as brakes and generate electricity to charge the batteries.

As a result, people who drive BEVs have a significant impact on the car's total energy consumption and range.

Batteries in BEVs have a lower energy density than gas or fuel, which is a drawback.

BATTERY FOR ELECTRIC VEHICLES

LITHIUM-ION BATTERIES

Lithium-ion batteries are used in the most of electric cars due to their high energy per unit mass compared to other electrical energy storage methods.

NICKEL-METAL HYDRIDE BATTERIES

Battery life is much longer with nickel-metal hydride batteries compared to lead-acid batteries. Additionally, they are safer and more resistant to mishandling.

LEAD-ACID BATTERIES

Lead-acid batteries have the potential to be developed to have a large capacity while being economical, safe, and reliable.

ULTRACAPACITORS

In ultra capacitors, the energy is stored in a polarized liquid between an electrode and an electrolyte, which is sandwiched between two electrodes.

BATTERY CELLS STRUCTURE USED IN ELECTRIC VEHICLES



Battery cell

It is a single unit that carries out the operations of a battery.



Battery module

A module is made by connecting multiple cells, encasing them in a metal case, and then connects them with terminals.



Battery pack

A pack is made up of several connected modules containing sensors and a controller, which are then housed in a case.

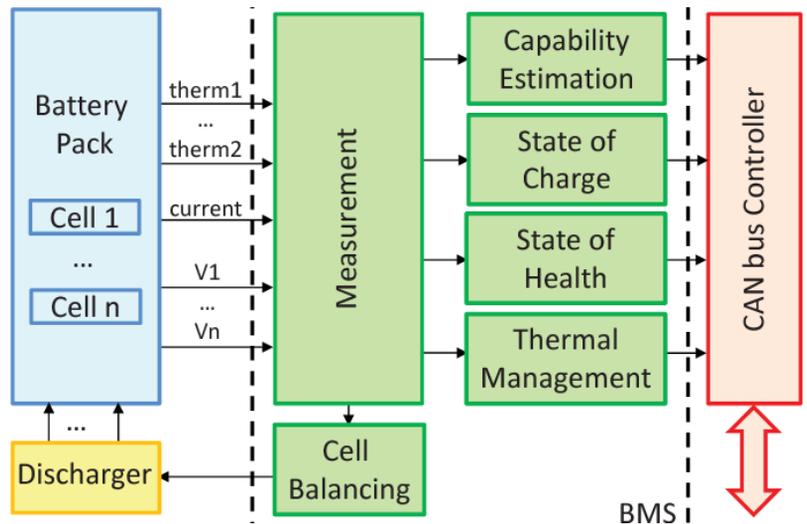
BATTERY PARAMETERS RELATED TO ELECTRIC VEHICLES

1. **Energy density** - The unit of measurement is presented in Watt-hours per kilogram (Wh/kg).
2. **Power density** – The measurement of how quickly the energy can be supplied.
3. **Gravimetric energy density** (specific energy) at cell and pack level .
4. **Battery C-rate** - The maximum charge or discharge current in relation to the battery's energy is described by the C-rate (in 1/h
5. **Number of battery cycles** – The maximum number of cycles a battery is able to withstand before its usable.

BATTERY MANAGEMENT SYSTEM (BMS) IN ELECTRIC VEHICLES

The BMS is responsible for managing the system during the EV/HEV vehicle's complete operational cycle and ensuring the following functions;

- ✓ **Analyzing data** of current, voltage, and temperature from the battery's sensor to ensure that the battery is operating properly.
- ✓ **Controlling the charger** to ensure that the battery is properly charged. The control is programmed to respond to data from the battery's sensor.
- ✓ **Managing cell balance** to provide the battery's best performance. In multi-cell batteries, balancing is required because the weakest cell lowers the battery's overall performance.



BMS diagram

Tutorial

Structure Question

1. List the types of alternative vehicles used in Green Transportation Systems.

[3 marks]

2. Compare the architecture diagram for parallel hybrid system and series/parallel hybrid systems in alternative vehicle used for green transportation.

[6 marks]

3. Explain the internal structure of Battery pack used in hybrid and Plug-in Electric Vehicles using appropriate diagram.

[6 marks]

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Main reference supporting the course

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2 Department of Electronics & Communication Engineering, Delhi Technical Campus, India
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