UNITV

DirectEnergyConversion

UNIT–V DIRECTENERGYCONVERSION

It is the method of transformation of one type of energy into another without passing through the intermediate stages such as steam, generators, etc. Most of these energy converters, sometimes called static energy-conversion devices, use electrons as their “working fluid” in place of the vapour or gas employed by such dynamic heat engines as the external combustion and internal-combustion engines mentioned above.

In recent years, direct energy-conversion devices have received much attention because of the necessity to develop more efficient ways of transforming available forms of primary energy into electric power. Direct energy-conversion devices are of interest for providing electric power in spacecraft because of their reliability and their lack of moving parts. As have solar cells, fuel cells, and thermoelectric generators, thermionic power converters have received considerable attention for space applications. Thermionic generators are designed to convert thermal energy directly into electricity.

Direct Energy Conversion devices like thermionic and thermoelectric converters are heat engines. The heat engine operates between two reservoirs to and from which heat can be transferred. We put heat into the system from the hot reservoir and heat is expelled into the cold reservoir.

The Carnot cycle:

The Carnot cycle is a theoretical thermodynamic cycle proposed by Nicolas Leonard Sadi Carnot. It can be shown that it is the most efficient cycle for converting a given amount of thermal energy into work, or conversely, creating a temperature difference (e.g. refrigeration) by doing a given amount of work. Every single thermodynamics system exists in a particular state. When a system is taken through a series of different states and finally returned to its initial state, a thermodynamic cycle is said to have occurred. In the process of going through this cycle, the system may perform work on its surroundings, thereby acting as a heat engine.

1. A system undergoing a Carnot cycle is called a Carnot heat engine, although such a "perfect" engine is only a theoretical limit and cannot be built in practice. The Carnot cycle when acting as a heat engine consists of the following steps:Reversible isothermal expansion of the gas at the "hot" temperature, T1 (isothermal heat addition or absorption). During this step the gas is allowed to expand and it does work on the surroundings. The temperature of the gas does not change during the process, and thus the expansion is isothermal. The gas expansion is propelled by absorption of heat energy Q1 and of entropy $\Delta S = Q1/T1$ from the high temperature reservoir.
2. Isentropic (reversible adiabatic) expansion of the gas (isentropic work output). For this step the mechanisms of the engine are assumed to be thermally insulated, thus they neither gain nor lose heat. The gas continues to expand, doing work on the surroundings, and losing an equivalent amount of internal energy. The gas expansion causes it to cool to the "cold" temperature, T2. The entropy remains unchanged.
3. Reversible isothermal compression of the gas at the "cold" temperature, T2 (isothermal heat rejection). Now the surroundings do work on the gas, causing an amount of heat energy Q2 and of entropy $\Delta S = Q2/T2$ to flow out of the gas to the low temperature reservoir. (This is the same amount of entropy absorbed in step 1, as can be seen from the Clausius inequality.)

4. Isentropic compression of the gas (isentropic work input). Once again the mechanisms of the engine are assumed to be thermally insulated. During this step, the surroundings do work on the gas, increasing its internal energy and compressing it, causing the temperature to rise to T1. The entropy remains unchanged. At this point the gas is in the same state as at the start of step 1.

Principles of DEC:

The pioneer in thermoelectric was a German scientist Thomas Johann Seebeck (1770–1831). Thermoelectricity refers to a class of phenomena in which a temperature difference creates an electric potential or an electric potential creates a temperature difference. A thermoelectric power generator is a device that converts the heat energy into electrical energy based on the principles of the Seebeck effect. Later, in 1834, French scientist Peltier and in 1851, Thomson (later Lord Kelvin) described the thermal effects on conductors.

See beckeffect:

When the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit. This is known as the See beck effect.

Peltier effect:

Whenever current passes through the circuit of two dissimilar conductors, depending on the current direction, either heat is absorbed or released at the junction of the two conductors. This is known as the Peltier effect.

Thomson effect:

Heat is absorbed or produced when current flows in material with a certain temperature gradient. The heat is proportional to both the electric current and the temperature gradient. This is known as the Thomson effect.

Thermo electric effect:

The thermoelectric effect is the direct conversion of heat differentials to electric voltage and vice versa. The good thermoelectric materials should possess large See beck coefficients, high electrical conductivity, and low thermal conductivity.

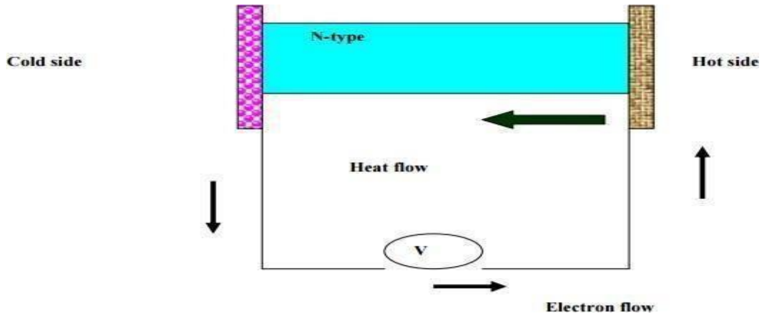
Principle, construction and working of Thermo electric power generator:

A thermoelectric power generator is based on the principle of the See beck effect: when the junctions of two different metals are maintained at different temperatures, an emf is produced in the circuit.

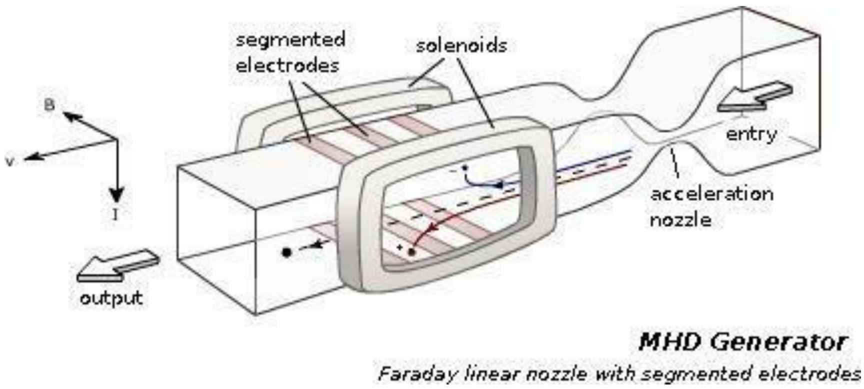
Construction:

Thermoelectric power generation (TEG) devices typically use special semiconductor materials, which are optimized for the See beck effect. The simplest thermoelectric power generator consists of a thermocouple, comprising a p-type and n-type material connected electrically in series and thermally in parallel. Heat is applied into one side of the couple and rejected from the opposite side. An electrical current is produced, proportional to the temperature gradient between the hot and cold junctions. For any TEPG, there are four basic components required such as heat source (fuel), P and N type semiconductor stack, heat sink (cold side), and electrical load (output voltage).

Working:



When the two sides of a semiconductor are maintained with different temperature, the emf flows across the output circuit.



MAGNETO – HYDRODYNAMICGENERATOR(MHD)

A magneto-hydrodynamic generator (MHD generator) is a magneto-hydrodynamic device that transforms thermal energy and kinetic energy into electricity. MHD generators are different from traditional electric generators in that they operate at high temperatures without moving parts. MHD was developed because the hot exhaust gas of an MHD generator can heat the boilers of a steam power plant.

Plant, increasing overall efficiency. MHD was developed as a topping cycle to increase the efficiency of electric generation, especially when burning coal or natural gas. MHD dynamos are the complement of MHD propulsors, which have been applied to pump liquid metals and in several experimental ship engines.
An MHD generator, like a conventional generator, relies on moving a conductor through a magnetic field to generate electric current. The MHD generator uses hot conductive plasma as the moving conductor. The mechanical dynamo, in contrast, uses the motion of mechanical devices to accomplish this. MHD generators are technically practice
al for-fossil fuels, but have been overtaken by other, less expensive technologies, such as combined cycles in which a gas turbines or molten carbonate fuel cell's exhaust heats steam to power a steam turbine.

Principle of MHD Generation

The principle of MHD power generation is very simple and is based on Faraday's law of electromagnetic induction, which states that when a conductor and a magnetic field move relative to each other, then voltage is induced in the conductor, which results in flow of current across the terminals.

As the name implies, the magnetohydrodynamics generator, shown in the figure below, is concerned with the flow of a conducting fluid in the presence of magnetic and electric fields. In a conventional generator or alternator, the conductor consists of copper windings or strips, while in an MHD generator the hot ionized gas or conducting fluid replaces the solid conductor.

A pressurized, electrically conducting fluid flows through a transverse magnetic field in a channel or duct. A pair of electrodes are located on the channel walls at right angle to the magnetic field and connected through an external circuit to deliver power to a load connected to it. Electrodes in the MHD generator perform the same function as brushes in a conventional DC generator. The MHD generator develops DC power and the conversion to AC is done using an inverter.

The power generated per unit length by MHD generator is approximately given by,

$$P = \frac{\sigma u B^2}{P}$$

Where, u is the fluid velocity, B is the magnetic flux density, σ is the electrical conductivity of conducting fluid, and P is the density of fluid.
It is evident from the equation above, that for the higher power density of an MHD generator there must be a strong magnetic field of 4–5 tesla and high flow velocity of conducting fluid besides adequate conductivity.

MHD Cycles and Working Fluids

The**MHDcycles**canbeoftwotypes,namely

1. OpenCycleMHD.
2. ClosedCycleMHD.

Open Cycle MHD System

In open cycle MHD system, atmospheric air at very high temperature and pressure is passed through the strong magnetic field. Coal is first processed and burned in the combustor at a high temperature of about 2700 °C and pressure about 12 ATP with pre-heated air from the plasma. Then a seeding material such as potassium carbonate is injected to the plasma to increase the electrical conductivity. The resulting mixture having an electrical conductivity of about 10 Siemens/m is expanded through a nozzle, so as to have a high velocity and then passed through the magnetic field of MHD generator. During the expansion of the gas at high temperature, the positive and negative ions move to the electrodes and thus constitute an electric current. The gas is then made to exhaust through the generator. Since the same air cannot be reused again, hence it forms an open cycle and thus is named as open cycle MHD.

Closed Cycle MHD System:

As the name suggests, the working fluid in a closed cycle MHD is circulated in a closed loop. Hence, in this case inert gas or liquid metal is used as the working fluid to transfer the heat. The liquid metal has typically the advantage of high electrical conductivity, hence the heat provided by the combustion material need not be too high. Contrary to the open loop system there is no inlet and outlet for the atmospheric air. Hence, the process is simplified to a great extent, as the same fluid is circulated time and again for effective heat transfer.

Advantages of MHD Generation:

The advantages of MHD generation over the other conventional methods of generation are given below.

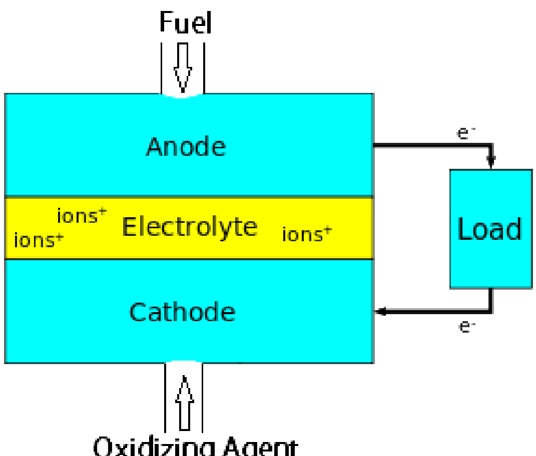
1. Here only working fluid is circulated, and there are no moving mechanical parts. This reduces the mechanical losses to nil and makes the operation more dependable.
2. The temperature of working fluid is maintained by the walls of MHD.
3. It has the ability to reach full power level almost directly.
4. The price of MHD generators is much lower than conventional generators.
5. MHD has very high efficiency, which is higher than most of the other conventional or non-conventional method of generation.

Fuel Cell: A fuel cell is an electric cell which produces electrical energy from chemical energy; through an oxidation reaction of provided fuel.

The main difference between normal secondary batteries and fuel cell is that; in secondary batteries the chemical energy is stored in the electrodes of the cell, but in fuel cell the chemical energy is stored in a fuel. And the fuel, oxidizing agent are stored outside of the cell and fed into the cell when electricity is to be produced. Example of fuel cell is Hydrogen Fuel cell or Hydrogen-Oxygen Fuel cell.

Construction of a Fuel Cell:

A fuel cell consists of two porous electrodes separated by an electrolytic solution in between. The fuel, which is usually Hydrogen or Carbon monoxide, is fed into one of the electrodes and a reacting agent, which is usually Oxygen or Air, is fed into another electrode. The electrodes are porous enough to pass through both fuels and electrolyte and also conduct electricity. The fuel and reacting agent react inside the fuel cell and produce electricity which can be obtained through terminals connected to the electrodes.



Advantages and Disadvantages of a Fuel Cell:

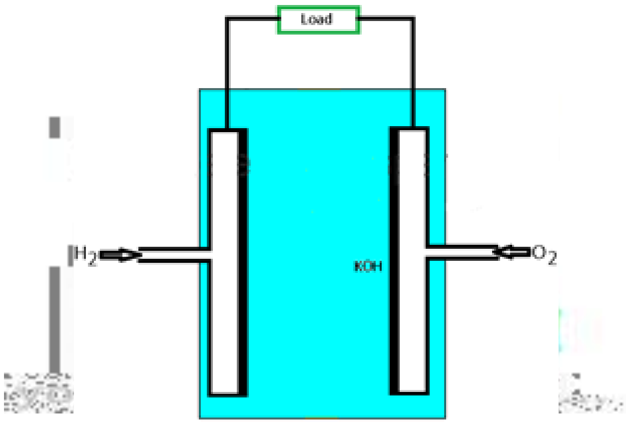
The electrode materials in a Fuel Cell are not changed during chemical reaction so a Fuel Cell does not require recharging, they can be used as a continuous generator as long as the fuel and oxidizing agent are supplied. Also, fuel cells do not have any moving parts; so, unlike normal generators they do not produce sound, require very little maintenance and produce no gases or fumes. Fuel cell's efficiency and cost per KW of power is independent of their size; so, they also offer a design flexibility and a room for further research and development.

But, the initial design and manufacturing cost of fuel cell is very high. They produce small voltages and also, their service life is not much as compared to other cells.

Hydrogen Fuel Cell:

Hydrogen Fuel cell or Hydrogen-Oxygen Fuel cell is one of the most basic type of fuel cell. Hydrogen fuel cell uses Hydrogen (H) as the fuel and Oxygen (O) is the oxidizing agent.

ThebasicconstructionofaHydrogen – OxygenFuelcellis:



The electrodes are made up of sintered Nickel plates having a coarse porous surface and a fine porous surface; the two surfaces for gas and electrolyte respectively. A solution of KOH is used as electrolyte. The water vapor formed during the reaction is passed back by condensation from the opening for passing hydrogen into the cell.

A continuous flow of Hydrogen and Oxygen is maintained. The Oxygen and Hydrogen react with potassium hydroxide at the surface of electrodes to produce electricity.