Lecture Notes

for

B.TECH. III yr, VIth Semester

(Electrical Engg.)

Subject Code: EE604

Subject: Power Station Practices

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EE – 604 POWER STATION PRACTICE
Syllabus

UNIT-I Introduction: Electric energy demand and growth in India, electric energy sources.
Thermal Power Plant: Site selection, general layout and operation of plant, detailed description and use of different parts.

Hydro Electric Plants: Classifications, location and site selection, detailed description of various components, general layout and operation of Plants, brief description of impulse, reaction, Kaplan and Francis turbines, advantages & disadvantages, hydro-potential in India.

UNIT-II Nuclear Power Plant: Location, site selection, general layout and operation of plant. Brief description of different types of reactors, moderator materials, fissile materials, control of nuclear reactors, disposal of nuclear waste material, shielding.

Gas Turbine Plant: Operational principle of gas turbine plant & its efficiency, fuels, open and closed-cycle plants, regeneration, inter-cooling and reheating, role and applications.

Diesel Plants: Diesel plant layout, components & their functions, its performance, role and applications.

UNIT-III Sub-stations Layout: Types of substations, bus-bar arrangements, typical layout of substation.

Power Plant Economics and Tariffs: Load curve, load duration curve, different factors related to plants and consumers, Cost of electrical energy, depreciation, generation cost, effect of load factor on unit cost. Fixed and operating cost of different plants, role of load diversity in power system economy; Objectives and forms of Tariff; Causes and effects of low power factor, advantages of power factor improvement, different methods for power factor improvements.
UNIT-IV Economic Operation of Power Systems: Characteristics of steam and hydro-plants, Constraints in operation, Economic load scheduling of thermal plants neglecting and considering transmission losses, Penalty factor, loss coefficients, incremental transmission loss; Hydrothermal Scheduling.

UNIT-V Non-Conventional Energy Sources: Power Crisis, future energy demand, role of private sectors in energy management,
MHD Generation: Working principle, open and closed cycles, MHD systems, advantages, parameters governing power output.
Solar Power Plant: Conversion of solar heat to electricity, solar energy collectors, photovoltaic cell, power generation, future prospects of solar energy use.
Wind Energy: Windmills, power output with combined operation of wind turbine generation and isolated generating system, technical choices & economic size.
Geothermal Energy: Earth energy, heat extraction, vapour turbine cycle, difficulties & disadvantages,
Tidal Energy: Tidal phenomenon, tidal barrage, tidal power schemes.
Ocean Thermal Energy: Introduction, energy conversion, problems.

Unit- 5 (Magnetohydrodynamic power generation)

Working principle of MHD generator

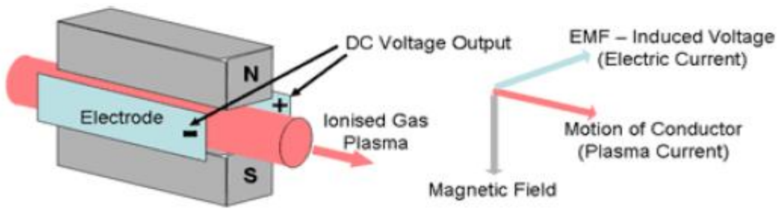
MHD generator:

MHD generators (MHD electrical power generators) are devices in which, according to the magneto hydrodynamics laws, a conversion of the energy of working fluid into electrical energy takes place. Magneto hydrodynamic power generation provides a way of generating electricity directly from a fast moving stream of ionised gases without the need for any moving mechanical parts - no turbines and no rotary generators. The principle of operation of MHD generators as well as conventional electrical generators is based on Faraday's induction law.

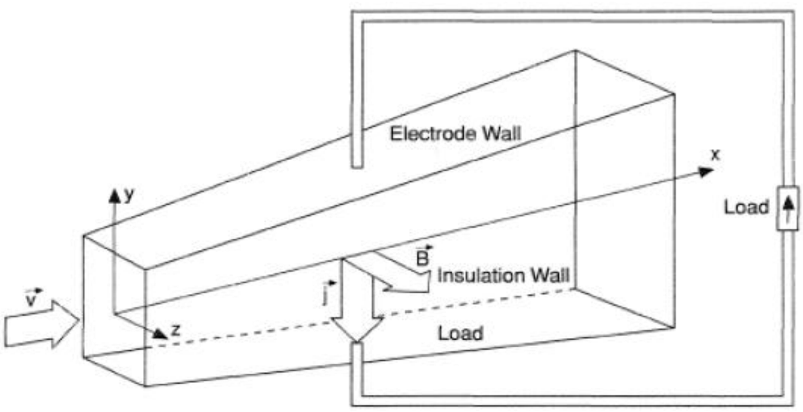
working principle :

The MHD generator can be considered to be a fluid dynamo. This is similar to a mechanical dynamo in which the motion of a metal conductor through a magnetic field creates a current in the conductor except that in the MHD generator the metal conductor is replaced by conducting gas plasma.

When a conductor moves through a magnetic field it creates an electrical field perpendicular to the magnetic field and the direction of movement of the conductor. This is the principle, discovered by Michael Faraday, behind the conventional rotary electricity generator. Dutch physicist Antoon Lorentz provided the mathematical theory to quantify its effects.



Magnetohydrodynamic Power Generation (Principle)



The flow (motion) of the conducting plasma through a magnetic field causes a voltage to be generated (and an associated current to flow) across the plasma , perpendicular to both the plasma flow and the magnetic field according to Fleming's Right Hand Rule.

Lorentz Law describing the effects of a charged particle moving in a constant magnetic field can be stated as

$$F = QvB$$

where

F is the force acting on the charged particle

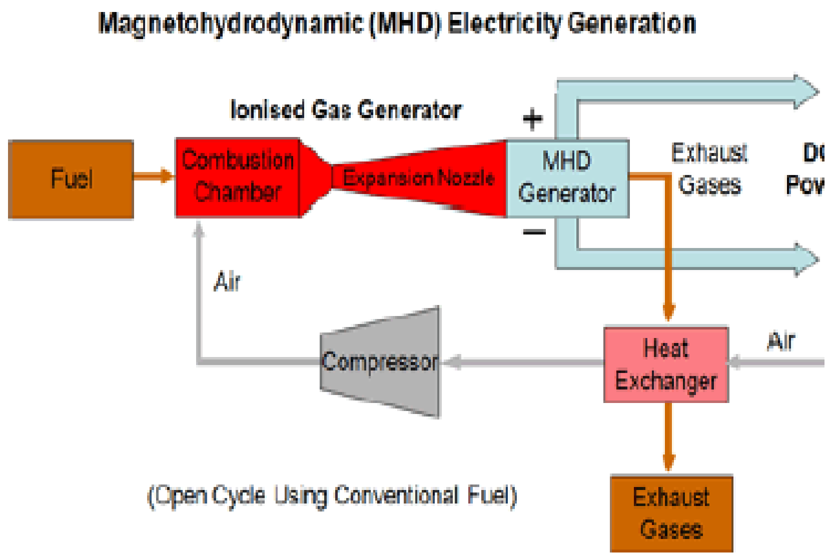
Q is charge of particle

v is velocity of particle

B is magnetic field.

MHD system :

The MHD generator needs a high temperature gas source, which could be the coolant from a nuclear reactor or more likely high temperature combustion gases generated by burning fossil fuels, including coal, in a combustion chamber. The diagram below shows possible system components.



The expansion nozzle reduces the gas pressure and consequently increases the plasma speed (Bernoulli's Law) through the generator duct to increase the power output (See Power below). Unfortunately, at the same time, the pressure drop causes the plasma temperature to fall (Gay-Lussac's) must be found.

The Plasma

The prime system requirement is creating and managing the conducting gas plasma since the system depends on the plasma having a high electrical conductivity. Suitable working fluids are gases derived from combustion, noble gases, and alkali metal vapours.

Faraday Current

A powerful electromagnet provides the magnetic field through which the plasma flows, and perpendicular to this field are installed the two electrodes on opposite sides of the plasma across which the electrical output voltage is generated. The current flowing across the plasma between these electrodes is called the Faraday current. This provides the main electrical output of the MHD generator.

The Hall Effect Current

The very high Faraday output current which flows across the plasma duct into the load itself reacts with the applied magnetic field creating a Hall Effect current perpendicular to the

Faraday current, in other words, a current along the axis of the plasma, resulting in lost energy. The total current generated will be the vector sum of the transverse (Faraday) and axial (Hall effect) current components. Unless it can be captured in some way, the Hall effect current will constitute an energy loss . components of the current in order to improve the overall MHD conversion efficiency.
One such method is to split the electrode pair into a series of segments physically side by side (parallel) but insulated from each other, with the segmented electrode pairs connected in series to achieve a higher voltage but with a lower current. Instead of the electrodes being directly opposite each other, perpendicular to the plasma stream, they are skewed at a slight angle from perpendicular to be in
line with the vector sum of the Faraday and Hall effect currents, as shown in the diagram below, thus allowing the maximum energy to be extracted from the plasma.

Power Output

The output power is proportional to the cross sectional area and the flow rate of the ionised plasma. The conductive substance is also cooled and slowed in this process. MHD generators typically reduce the temperature of the conductive substance from plasma temperatures to just over 1000 °C.

Efficiency

Typical efficiencies of MHD generators are around 10 to 20 percent mainly due to the heat lost through the high temperature exhaust. This limits the MHD's potential applications as a stand alone device but they were originally designed to be used in combination with other energy converters in hybrid applications where the output gases (flames) are possible in such arrangements.

Types of MHD System

1. **Open-Cycle MHD system**

In this system, fuel used maybe oil through an oil tank or gasified coal through a coal gasification plant. The fuel (coal, oil or natural gas) is burnt in the combustor or combustion chamber. The hot gases from combustor is then seeded with a small amount of an ionized alkali metal (cesium or potassium), to increase the electrical conductivity of the gas. The seed material, generally potassium carbonate, is injected into the combustion chamber, the potassium is then ionized by the hot combustion gases at temperatures of roughly (2300 to 2700°C). To attain such high temperatures, the compressed air used to burn the coal (or other fuel) in the combustion chamber, must be preheated to at least 1100'C. A lower preheat temperature would be adequate if the air were enriched in oxygen. An alternative is to use compressed oxygen alone for combustion of the fuel, little or no pre heating is then required. The additional cost of the oxygen might be balanced by the savings on the pre heater. The hot, pressurized working fluid leaving the combustor flows through a convergent-divergent nozzle similar to a rocket nozzle.' In passing through the nozzle, the random motion energy of the molecules in the hot gas is largely converted into directed, mass motion energy. Thus, the gas emerges from the nozzle and enters the MHD generator unit at a high velocity.
The MHD generator is a divergent channel (or duct) made of a heat-resistant alloy (e.g. Inconel) with external water cooling. The hot gas expands through the rocket like generator surrounded hy powerful magnet. During the motion of the gas the positive and negative ions move to the electrodes and constitute an electric current. The magnetic field direction, which is at right angles to the fluid flow, would be perpendicular to the plane of paper. A number of

oppositely located electrode pairs are inserted in the channel to conduct the electric current generated to an external load. The electrodes pair may be connected in various ways (see below) one of which is shown in. An MHD generator, unlike a conventional generator, produced direct current, this can be converted into commonly used alternating current by means of an inverter. The arrangement of the electrode connections is determined by the need to reduce losses arising from the Hall effect. By this effect, the magnetic field acts on the MHD—generated (Faraday) current and produces a voltage in t h e flow direction of the working fluid rather t h an at right angles to it. The resulting current in an external load is then called the Hall current. Various electrode connection schemes have been proposed to utilize the Faraday current while minimizing the Hall current. A simple way, although not the best is shown in Fig. Abetter, but more complicated, alternative is to connect each electrode pair across a separate load, as in Fig. Another possibility is to utilize the Hall current only ; each electrode pair is short-circuited outside the or other fossil fuel), the problem of nitrogen oxide formation does not arise. However, if nitrogen (from air) is present, the nitrogen oxide content of the combustion gases will be high because of the required high temperature of the working fluid. Consequently, a controlled combustion procedure is used to reduce the nitrogen oxide level in the discharge flue gas. The air supplied to the combustion chamber is not sufficient to permit complete fuel burning; combustion of the unburned fuel gases is then completed by introducing additional air at a later stage, beyond the MHD generator- The lower combustion temperature is accompanied by a decrease in the nitrogen oxide concentration. For efficient practical realization an MHD system must have the following features:

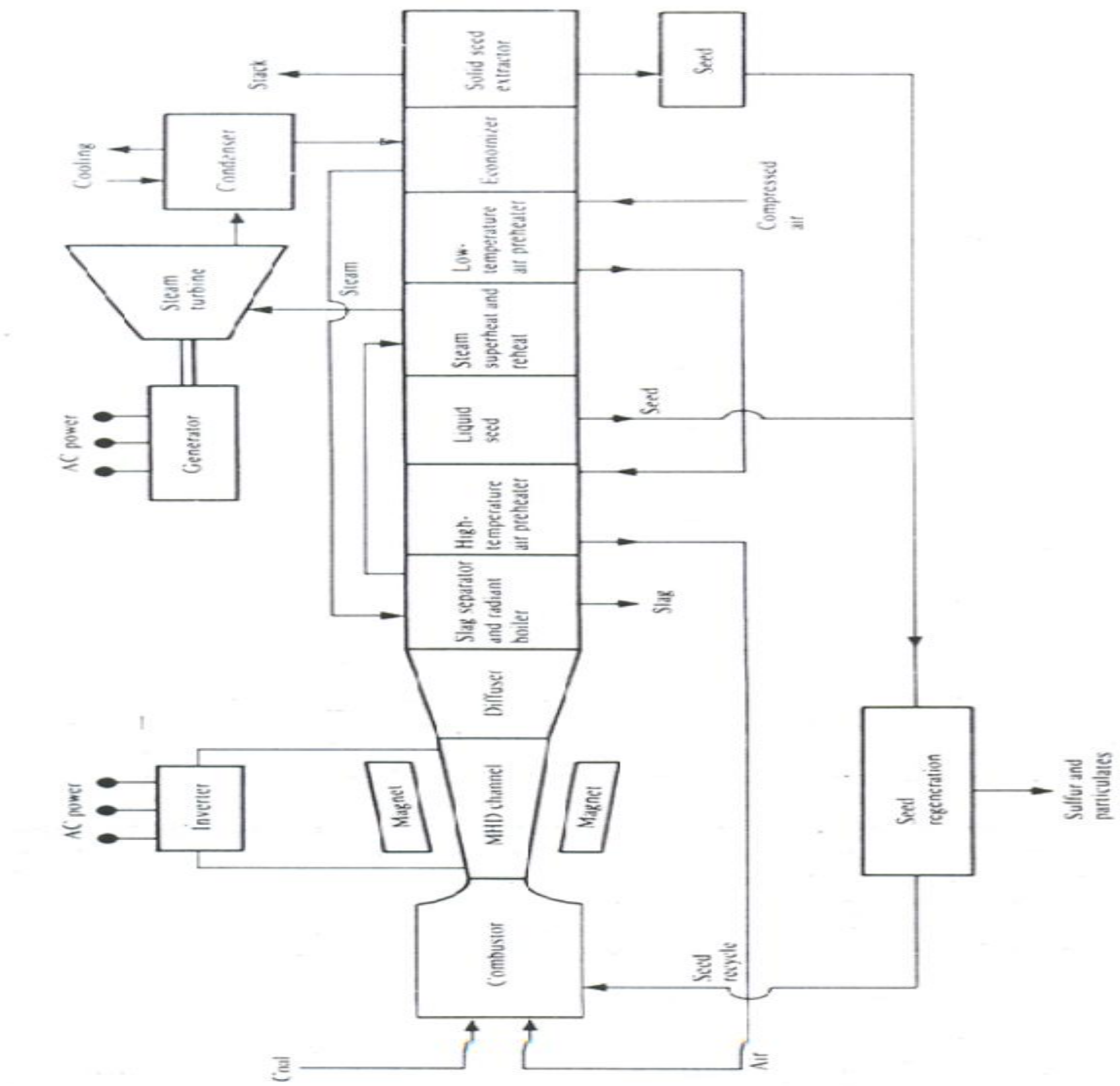
1- Air super heating arrangement to heat the gas to around 2500°C, (the inlet temperature of MHD is about 2500"C), so that the electrical conductivity of the gas is increased.

2. The combustion chamber must have low heat losses.

3. Arrangement to add a low ionization potential seed material to the gas to increase its conductivity.

4. A water cooled but electrically insulating expanding duct with long life electrodes.

5. Seed recovery apparatus—necessary for both environmental and economic reasons.



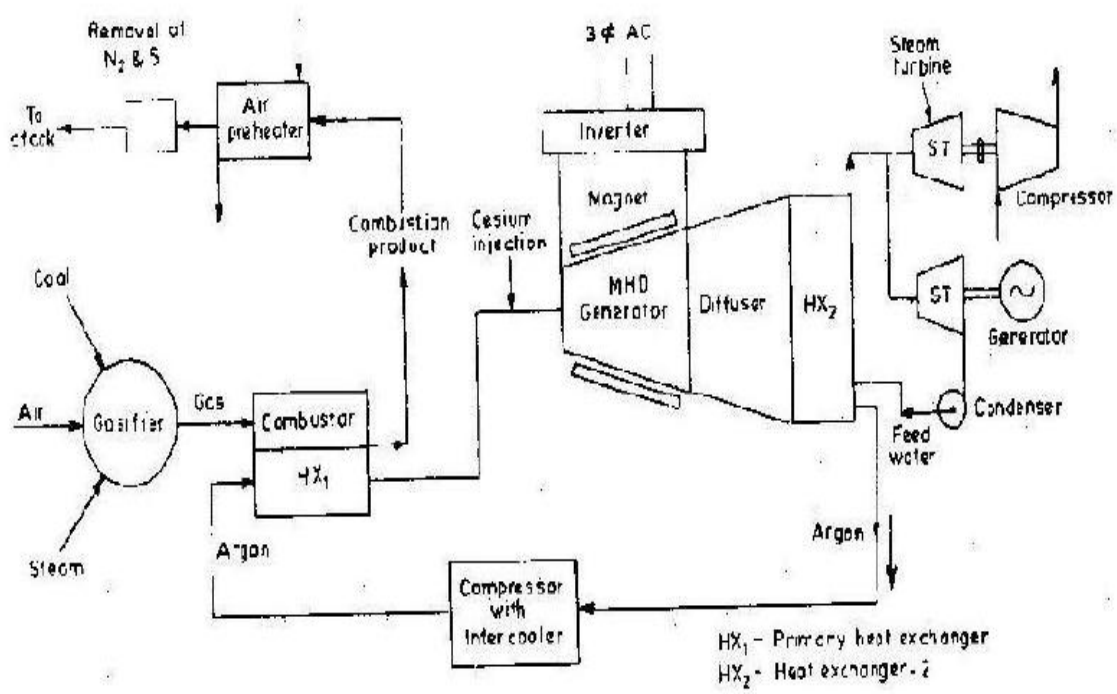
2. **Closed-cycle (Seeded inert gas) MHD systems**

Two general types of closed cycle MHD generators are being investigated. In one type, electrical conductivity is maintained in the working fluid by ionization of a seed material, as in open-cycle systems and in the other, a liquid metal provides the conductivity.The carrier is usually a chemical inert gas, although a liquid carrier has been used with a liquid metal conductor. The working fluid is circulated in a closed loop and is heated by the combustion gases using a heat exchanger.Hence, the heat source and the working fluid are independent. The working fluid is helium or argon with cesium seeding.

Seeded inert gas system :

In a closed cycle system the carrier gas (argon/helium) operates in a form of Bray ton cycle. The gas is compressed and heat is supplied by the source, at essentially constant pressure; the compressed gas then expands in the MHD generator and its pressure and temperature fall. After leaving the generator, heat is removed from the gas by a cooler, this is the heat rejection stage of the cycle. Finally the gas is recompressed and returned for reheating. A closed cycle

MHD system is shown in Fig. The complete system has three distinct but interlocking loops. On the left is the external heating loop. Coal is gasified and the gas (having a high the MHD cycle. The combustion products after passing through the air preheated (to recover a part of t he heat of combustion products) and purifier (to remove harmful emissions) are discharged to atmosphere. Because the combustion system is separate from the working fluid, so also are the ash and flue gases. Hence, the problem of extracting the seed material from flyash does not arise. The flue gases are used to preheat the incoming combustion air and then treated for fly ash and sulphur-dioxide removal, if necessary, prior to discharge through a stack to the atmosphere. The loop in the centre is the MHD loop. The hot argon gas is seeded with cesium and resulting working fluid is passed through the MHD generator at high speeds. The d.c. power out of MHD generator is converted to A.C. by the inverter and is then fed into the grid. The loop shown on the right hand side in figure is the steam loop for further recovery of the heat of working fluid and converting this heat into electrical energy in the diffuser the working fluid is slowed down to a low subsonic speed. Then hot fluid enters a secondary heat exchanger, which serves as a waste heat boiler to generate steam. This steam is partly utilized to drive a turbine generator and for driving a turbine which runs the argon (or helium) compressor. The output of the generator is also fed to the main grid. The working fluid is returned back to primary heat exchanger after passing through compressor and inter cooler. A closed cycle system can provide more useful power conversion at lower temperature (around 1900°K as compared to 2500° K for open cycle system). The somewhat lower operating temperatures of a closed cycle, MHD converter than of an open cycle system have an advantage in permitting a wider choice of materials. On the other hand, the lower temperature of the working fluid also means a lower thermal efficiency. Furthermore temperatures in the combustion chamber are still high, and special construction materials are required for the primary heat exchanger. Moreover the working fluid must be kept absolutely pure. The electrical stability of the flow in the generator poses problems because the gas is subjected to electrical fields approaching breakdown conditions. The closed cycle MHD using rare gases as working fluid is developed and it is the most promising system among all. Generally, the heat source used is gas cooled nuclear reactor.



Advantages and Disadvantage of MHD Systems

Advantages :

(1) The conversion efficiency of an MHD system can be around 50 per cent as compared to less than 40 per cent for the most efficient steam plants. Still higher thermal efficiencies (60-65%) are expected in future, with the improvements in experience and technology.
(2) Large amount of power is generated.
(3) It has no moving parts, BO more reliable.
(4) The closed cycle system produces power free of pollution.
(5) It has ability to reach the full power level as soon as started.
(6) The size of the plant (m2/kW) is considerably smaller than conventional fossil fuel plants.
(7) Although the costs can not be predicted very accurately, yet it has been reported that capital costs ofMHD plants will be competitive with those of conventional steam plants.
(8) It has been estimated that the overall operational, costs in an MHD plant would be about 20% less than in conventional steam plants.
(9) Direct conversion of heat into electricity permits to eliminate the gas turbine (compared with a gas turbine power plant) or both the boiler and the turbine (compared with a steam power plant). This elimination reduces losses of energy.
(10) These systems permit better fuel utilization. The reduced fuel consumption would offer additional economic and special benefits and would also lead to conservation of energy resources.
(11) It is possible to utilize MHD for peak power generations and emergency service (upto 100 hours per year). It has bepn estimated the MHD equipment for such duties is simpler, has the capability of generating in large units and has the ability to make rapid start to full load.

Disadvantages:

1. Numerous technological advancement requires prior to its commercialisation.
2. It requires highly corrosive and abrasive environment.
3. MHD channels operates under extream condition of temperature.