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MAGNETO-HYDRO-DYNAMICS (MHD) GENERATION

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ABSTRACT

Energy Technology is an applied science dealing with various alternative energy routes comprising the exploration and extraction of primary raw energy, conversions to intermediate/secondary forms of energy and by-products, transportation alternatives, storage, distribution and supply of secondary forms of energy.

In India, and many other developing Nations, the gap between the demand and supply of secondary energy is increasing resulting in perpetual energy crises. Besides many methods of power generation like thermal, nuclear, diesel etc. one of the high efficient and unique methods with pollution free environment is Magneto Hydro Dynamic (MHD) type power generation. It is a way of generating electricity by conversion of heat into electrical energy, without the need of any moving mechanical parts- no turbines and no rotary generators. Therefore due to the elimination of link process of producing mechanical energy and then converting it to electrical energy, the fuel economy can be achieved. Basically the efficiency of non-conventional power plant like solar, wind, tidal are around of 35-40%, whereas of MHD power plant is about 50-60% which can be raised up to 75-80% by using super conducting magnets. Hence using MHD power generation technique the crises of energy can be reduced up to certain limits.

I. INTRODUCTION

Magneto hydrodynamics is a science concerned with the interaction between magnetic field, flow of hot electrically ionized fluid (gaseous or liquid) and generation of electrical field. MHD generators convert thermal energy to electrical energy directly (without rotating machines).

The magneto-hydro-dynamics involves:

- Strong magnetic fields (5 to 6 T)
- Flowing ionized fluid at high temperature containing thermal energy and Enthalpy. The conventional turbine generators units are totally absent. The plant for producing electrical energy by MHD is called MHD Power Plant or MHD Generator.

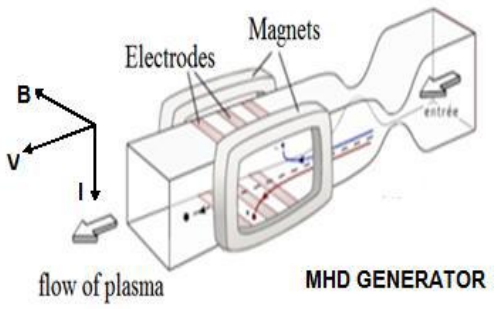


FIGURE:-1

MHD plant receives coal or gasified coal as fuel. MHD generator is used as a topping cycle unit with steam turbine generator as a bottoming unit. The MHD-Steam hybrid plant has net thermal efficiency 50-60% as compared to 30-40% of conventional coal fired steam turbine generator plant. Due to higher efficiency of MHD, the fuel consumption of primary energy input will be lesser and fuel like coal, gas will be conserved.

The MHD generator is without any rotating parts or moving parts. Hence, maintenance requirements are expected to be modest. Due to this vital advantage, substantial efforts have been devoted to development of MHD Plant Technology since 1959. Interest in MHD has further increased after the 1973 oil crises.

II. HISTORY

- During the Bakerian lecture to the Royal Society in the year 1832, Michael Faraday introduced the concept of MHD power generation for the very first time. However the concept remained unthinkable for its actual utilization.
- Around 1938, at Westing house research laboratory (USA), the first known attempt to develop an MHD generator was made.

HISTORICAL REVIEW OF MHD.

1959	USA	First Demonstration Facility to prove feasibility.
1960	USSR Japan, France UK, USA, Poland	Research and development projects initiated.
1970	USSR	Pilot plant rated 25 MW was commissioned.
1977 1985	India	Pilot plant stage I rated 5MW was initiated (BHEL). The pilot plant Commissioned.
1986	USSR	First commercial MHD plant rated 500 MW commissioned in former USSR at Ryazan Central Power Station. It has two units of 250 MW each.
1987	USA	Several 50 MW and 100MW MHD Generators are undergoing field trials.
1990		Liquid Metal Closed Cycle MHD cycle under development.

III. PRINCIPLE

The MHD power generation principle is very simple and is based on Faradays law of Electromagnetic Induction which actually states that when a conductor and a magnetic field moves relative to each other, then voltage is induced in the conductor, which results in flow of current across the terminals.

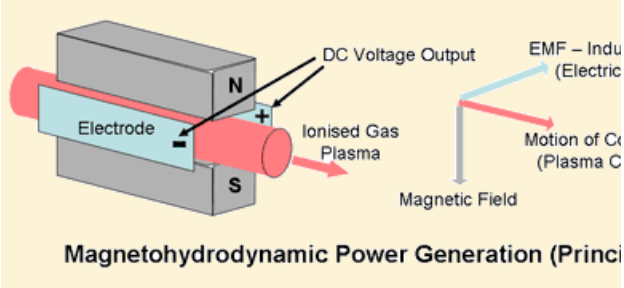


FIGURE:-2

The voltage generated across the electrodes due to the flow of the conducting plasma through a magnetic field at high velocity is perpendicular to both the plasma flow and the magnetic field according to Flemings Right Hand Rule.
The effect of a charged particle moving in a constant magnetic field is described by the Lorentz Force Law. The simplest form of this law is given by the vector equation.

F=Q. (v x B)

Where,

- F is the force acting on the particle.
- Q is the charge of the particle,
- v is the velocity of the particle, and
- B is the magnetic field.

The vector F is perpendicular to both v and B according to the right hand rule.

IV. CONSTRUCTION

Basically the construction of MHD generators is very simple. As it consists of no moving parts and actual conductors are replaced by plasma (ionized gas), the construction becomes easier.

The main components in the MHD Generator are:

- **DUCT:** The hot ionized gases flow through the duct. The duct has a convergent-divergent shape such that the gases attain supersonic velocity in the divergent portion. Cross section of duct is either rectangular or circular.

- **COMBUSTOR:** The fuel, hot compressed air and seeding material are admitted in the combustor. The fuel is ignited by auxillary burners. Fuel is burnt to obtain hot gases at high temperature (2500-3000 K) and high pressure. The seeding (ionizing) material is mixed with the hot gases to obtain Ionized gas. Seeding material is potassium or Cesium. The hot ionized gas is called the working fluid. The fluid is accelerated to almost supersonic speeds in the divergent portion of the duct.

- **ELECTROMAGNET FIELD COILS:** The magnetic field coils are placed such that the magnetic field is

in direction perpendicular to the axis of the duct. The fields coils are energized by auxillary DC supply obtain from a rectifier set. The field coils are generally superconducting DC. Auxillary DC power supply is given by the MHD generator. Set via rectifier.

- **ELECTRODE SYSTEM:** Two sets of Segmented Electrodes (+ and -) are placed in the direction of the electrical field E which is perpendicular to B and HG. The power generated by the MHD is of DC form. The electrode system collects the power. The bus bar connections are provided between the electrode system and the Inverter. Electrodes are segmented and skewed to offset the drifting caused by the Hall Effect.

Basically there are two types of MHD systems:

1) Open cycle MHD system.
2) Closed cycle MHD system.

Open Cycle MHD System

In open cycle MHD system, atmospheric air is passed through the strong magnetic field at very high temperature and pressure. Coal is first processed and burnet in the combustor at a high temperature of about 2700°C and pressure about 12 atp with pre-heated air from the plasma. Then to increase the electrical conductivity, a seeding material such as potassium carbonate is injected to the plasma. To have a high velocity, resulting mixture having an electrical conductivity of about 10 Siemens'/m is expanded through a nozzle, and then passed through the magnetic field of MHD generator. The positive and negative ions move to the electrodes during the expansion of the gas at high temperature, 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.

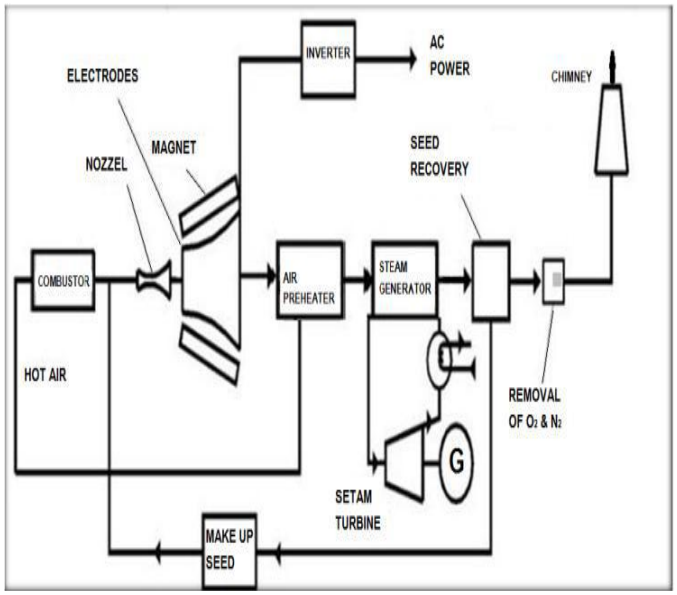


FIGURE:-3

Closed Cycle MHD System

As the name suggests the working fluid is circulated in a closed loop in a closed cycle MHD. Hence, in this case liquid metal or inert gas 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. Comparatively to the open loop system there is no inlet and outlet for the atmospheric air. As the same fluid is circulated again for effective heat transfer, this process is simplified to a great extent.

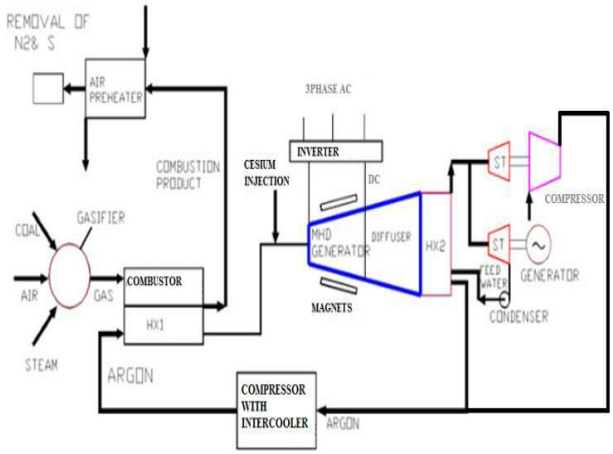


FIGURE:-4

V. WORKING

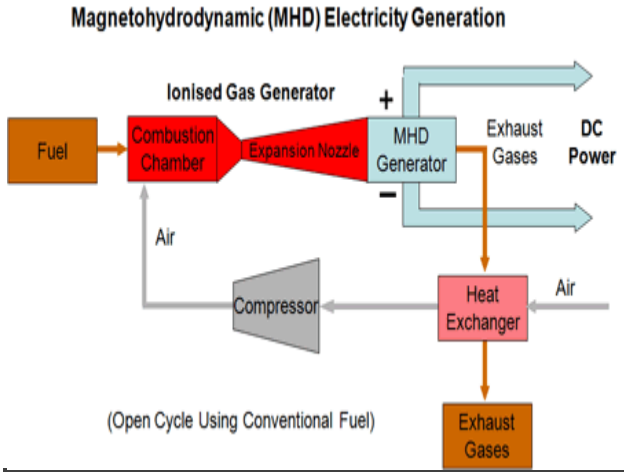


FIGURE:-5

The thermal energy is converted directly to direct current electrical energy by flowing hot seeded (ionized) gases through strong magnetic field. (Hence the name Magneto-Hydro-Dynamics). In a Magneto hydrodynamics Generator the magnetic field (B) is unidirectional. Hot ionized Gas is flown through the magnetic field in perpendicular direction.

By interaction between moving ionized gas (U) and the direct magnetic field (B), DC electric field (E) is generated in the third direction such that U, B, and E are mutually perpendicular. Direction of electric field is given by vector cross product:

$$\mathbf{U \times B = E}$$

Electrodes placed in the path of electric field collect the induced DC electromotive force (emf). When external electric circuit is connected, induced currents flow. The charged particles flow through the plasma in the direction of electric field and constitute DC current. The external Inverter converts DC to 3 Phase AC and supplies power to the AC network.

Thermal Energy in hot gases is converted to electrical energy supplied via the electrodes to the output circuit. The power supplied to DC magnetic coils is amplified to several thousand times.

VI. ADVANTAGES

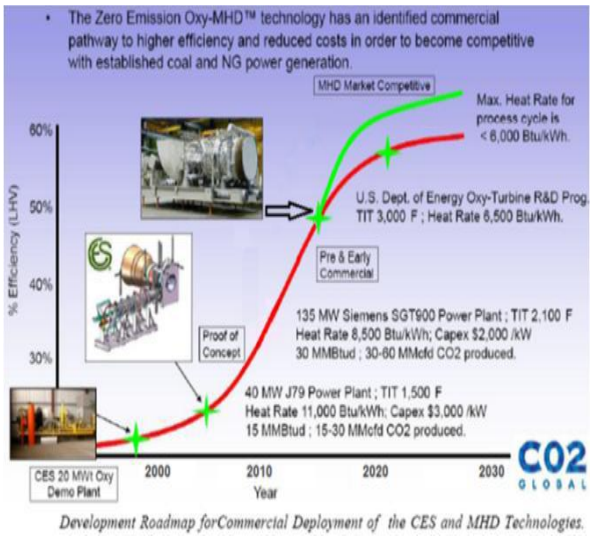
- MHD top-steam bottom plants have overall thermal efficiency of 50-55% as against the maximum 30-40% of the best among conventional steam power plants. This means fuel consumption and emission would reduce by 15% to 25%.
- Effective and simple technology.
- Energy losses can be reduced, as there is no moving part in the generator.
- Reduce Environmental Pollution.

VII. DISADVANTAGES

- High temperatures required by MHD (2500-3000 K) and high magnetic flux densities (5 to 6 Tesla) involving costly superconducting magnet technologies.
- The high temperature combustion of coal involves material problems and pollution problems.
- For small MHD plants of more than 1kW electrical capacity, construction of superconducting magnets, is only on the drawing board.
- Construction cost of generator is very high.

VIII. CONCLUSION

- In future, with Coal Gasification Technology, Nuclear Fusion Technology, Hydrogen Technology etc. MHD route may gain acceptance as a topping unit for steam power plants and gas turbine power plants.
- MHD Steam plants are preferable to conventional steam power plants. However technological problems related with design, materials, high temperatures, reliability, long service life etc are under investigation in several countries on pilot plants. MHD prospects are favourable.
- In upcoming decade, this system will be most significant as the practical efficiency of such power generation will not be less than 60%.



Development Roadmap forCommercial Deployment of the CES and MHD Technologies.

FIGURE:-6

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